CJCSI 6130.01A
13 February 1998

1998 CJCS MASTER POSITIONING, NAVIGATION, AND TIMING PLAN

JOINT STAFF
WASHINGTON, D.C. 20318-0400

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CHAIRMAN OF THE JOINT CHIEFS OF STAFF INSTRUCTION

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References: a. CJCSI 3170.01, 13 June 1997, "Requirements Generation System"
b. DOD Directive 4650.5, 5 December 1990, "Positioning and Navigation Systems Administration and Planning"
c. DOT-VNTSC-RSPA-97-2/DoD-4650-5, "1996 Federal Radionavigation Plan"
d. "Global Positioning System Standard Positioning Service Signal Specification," 2 June 1995, 2d Edition
e. "DoD Global Positioning System Security Policy," April 1992, Rev. May 1993
f. US Global Positioning System Policy, Presidential Decision Directive, (PDD)NSTC-6, 28 March 1996

1. Purpose. This instruction implements DOD positioning, navigation, and timing (PNT) policy and provides consolidated CJCS instructions to PNT developers and users. It identifies the roles and responsibilities of PNT users, developers, and supporting DOD elements. In recognition of the four emerging operational concepts presented in Joint Vision 2010, this CJCS Master Positioning, Navigation, and Timing Plan (MPNTP) provides the backbone of PNT information management for the US warfighter. This plan also informs the Services about major DOD PNT R&D activities. As such, it provides a broad, consolidated PNT information base to ensure consistent, informed management decisions and better allocation of Service resources.

a. This plan implements CJCS joint systems responsibilities. It provides the policy and planning bases for PNT requirements, compares requirements to existing technology, identifies performance shortfalls, highlights needed research and development, and provides long-term projections of anticipated capabilities.

b. Service and Defense agencies' PNT requirements are validated in accordance with reference a. The resulting validated programs are reflected in this plan and become the basis for the Services' and Defense agencies' PNT programming and Program Objective Memorandum (POM) submissions to the Office of the Secretary of Defense (OSD). This plan, directed by reference b, is additionally the DOD input to the Federal Radionavigation Plan (FRP) (reference c) and appropriate NATO plans.

2. Cancellation. CJCSI 6130.01, 20 May 1994, "CJCS Master Navigation Plan," is hereby canceled.

3. Applicability. This plan applies to the Military Departments, the Chairman of the Joint Chiefs of Staff (Joint Staff), the combatant commands, and the Defense agencies.

4. Policy. DOD policy requires a consistent and logical integration of PNT systems. This includes integrating the data, schedules, programs, plans, and responsibilities for navigation systems among the Services, Defense agencies, and commands, and between the MPNTP and the FRP. This plan provides the basis and vehicle for such integration. Enclosures D, E, and F contain additional DOD policies regarding development, operation, acquisition, security controls, and use of the Global Positioning System(GPS). This plan may be repromulgated, as required.

5. Responsibilities. See Enclosure A, paragraph 4, sections a through l.

6. Review Procedures. This CJCS MPNTP will be reviewed annually for correctness and completeness. It will be revised as necessary, normally during odd-numbered years. Recommendations for changes from the unified commands should be submitted to the Deputy Director for C4 Systems, J-6, Joint Staff, Washington, D.C. 20318-6000. Service and Defense agency recommendations should be submitted through the following addressees:

a. US Army. Deputy Chief of Staff for Operations and Plans, Attn.: DAMO-FDC, 400 Army Pentagon, Washington, D.C. 20310-0400.

b. USN. Chief of Naval Operations, Attn.: N63, Washington, D.C. 20350-2000.

c. USAF. Directorate of Operations, HQ Air Force, Airspace and Air Traffic Control Division (HQ USAF/XOOA), Washington, D.C. 20330-1480.

d. USMC. Commandant of the Marine Corps, Attn.: HQMC Code CSB, Washington, D.C. 20380-0001.

e. NSA. Director, National Security Agency, Attn.: DDI, Ft. George G. Meade, MD 20755-6000.

f. DISA. Director, Defense Information Systems Agency, Attn.: DNSO, Transmission Networks Management, 701 South Courthouse Road, Arlington, VA 22204-2199.

g. NIMA. Director, NIMA, Attn.: SA, 8613 Lee Highway, Fairfax, VA 22031-2137.

7. Effective Date. This instruction is effective immediately.

For the Chairman of the Joint Chiefs of Staff:

/Signature/
DENNIS C. BLAIR
Vice Admiral, U.S. Navy
Director, Joint Staff

Enclosures:
A--Introduction
B--Positioning, Navigation, and Timing Policy
C--Positioning, Navigation, and Timing System Architecture
D--GPS Operations and Security Policy
E--GPS User Equipment Acquisition Policy
F--Operational PNT Systems--Descriptions and Characteristics
G--Research and Development
H--Control of PNT Systems in Times of Tension or War
I--Geospatial Information and Services
J--Precise Time and Time Interval
Glossary

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Secretary, Joint Staff	60

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LIST OF EFFECTIVE PAGES

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PAGE	CHANGE	PAGE	CHANGE
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C-1 thru C-10	0	J-1 thru J-10	0
D-1 thru D-10	0	GL-1 thru GL-6	0
E-1 thru E-2	0		

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RECORD OF CHANGES

Change No.	Date of Change	Date Entered	Name of Person Entering Change

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ENCLOSURE A

INTRODUCTION

1. Scope. This plan covers major DOD PNT R&D planning and operational activities and presents the policies for those activities. It describes and presents the status of all operational DOD PNT systems. It also describes and presents the status of major DOD PNT R&D programs including objectives and plans. Additionally, this plan describes the activities of major military and civilian "common-use" systems and single-Service PNT systems. This comprehensive presentation is designed to inform DOD planners and operators so that they may be able to assess the impact on DOD-wide capabilities, requirements, and plans.

a. The MPNTP also contains a PNT systems plan. This systems plan projects system deployments and replacements for the benefit of planners and users.

b. The PNT systems described in this plan use the basic performance parameters developed by the Joint DOD/DOT Working Group on the Federal Radionavigation Plan. PNT systems are further categorized by primary function and method of operation.

c. This plan does not cover every possible topic of timing, positioning, or navigation. For example, it makes no detailed reference to celestial or visual navigation, nor to such topics as use of navigation charts or notices to mariners.

d. This plan uses the term PNT to apply to both the end use of positioning, velocity, and timing (PVT) information as well as to the various systems which generate PVT information.

2. Summary of Key PNT Policies

a. General Military Policy. Joint Vision 2010 provides the conceptual template on how the US Armed Forces will channel the vitality and innovation of people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting. JV 2010 provides a vision of future warfighting which embodies the improved intelligence and command and control available in the information age. The vision develops four operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics. In conducting these military operations, it is essential that PNT services be available with the highest possible confidence. These services must meet or exceed mission requirements. To meet these requirements, military operators must use a mix of independent, self-contained, self-initiated, and externally referenced systems. This mix assures the availability and capability of these essential PNT services. Services will develop PNT systems that will allow these independent systems to provide synergistic benefits and graceful degradation through physical and data integration. DOD PNT users may use US civil PNT systems for peacetime operations where their use does not jeopardize DOD's ability to carry out its military mission. US civil PNT systems purchased for peacetime operations will not be used in combat operations. Use of foreign PNT systems that are not provided by countries with defense arrangements with the Department of Defense are prohibited. The preceding prohibitions do not apply to ships and aircraft in peacetime PNT scenarios as long as the system(s) in use are IMO or ICAO recognized systems, respectively.

b. Survivability Requirements. PNT systems must be as survivable and enduring as the forces and weapon systems they are designed to support. The services should use physical security, hardening, electronic protection mechanisms, and other measures to ensure the availability of PNT services to the US and its allies, while denying such capabilities to enemies.

c. Continuity. Currently operational systems, and planned and ongoing system modifications must continue until developing systems have demonstrated their ability to satisfy operational requirements efficiently and economically.

d. Need for Periodic Reviews. Although general military PNT requirements remain fairly constant, the Department of Defense must continually review these requirements. New technology, weapon system modifications, the dynamics of national policy interests, and the nonmilitary environment in which the military must respond continue to influence requirements. Also, no definitive conclusions on long-term system mixes can be made without making speculative assumptions concerning future scenarios. Radionavigation systems will experience continuing changes in capabilities, threats, and requirements. Maintainability, vulnerability, and survivability also must be continually assessed. Therefore, maintaining the currency and usefulness of this plan will require continuing reviews and updates to periodically re-assess these changes and incorporate these reassessments in revised PNT planning.

e. Global Positioning System. GPS will be the primary radionavigation system source of PNT information for the Department of Defense. All DOD combatant users must acquire, train with, and use GPS systems capable of receiving the encrypted, military GPS signal, the Precise Positioning Service (PPS). DOD PNT users may use civilian GPS augmentations where their use does not jeopardize DOD's ability to carry out its military mission. Examples include the Federal Aviation Administration's developing Wide Area Augmentation System (WAAS), its Local Area Augmentation System (LAAS), and the US Coast Guard's Differential GPS (DGPS). It is essential for users to understand that these systems may not be reliable during conflict. They do not currently incorporate the same level of security and survivability as military systems. Enclosures D, E, and F contain detailed GPS research, acquisition, operating, and security policies.

3. Changes from the Previous Edition and Status of Current Issues

a. Changes from the Previous Edition. This plan reflects the President's policy guidance on military and civil GPS use, as stated in Presidential Decision Directive (PDD) NSTC-6 (reference f). While many of these policies are continuations of policies assumed in the previous edition of the MPNTP, key aspects are summarized in items 1-5, below.

(1) The United States will continue to provide GPS Standard Positioning Service (SPS) for peaceful civil, commercial, and scientific use on a continuous, worldwide basis, free of direct user fees.

(2) The United States intends to discontinue GPS Selective Availability (SA) by 2006, consistent with military capabilities to operate without SA. Beginning in 2000, the President will make an annual determination on continuing the use of SA.

(3) The United States will advocate international acceptance of GPS and US Government (USG) augmentations as international standards.

(4) To the fullest extent feasible, the USG will purchase commercially available GPS products and services that meet USG requirements. The USG will not conduct activities that preclude or deter commercial GPS activities, except for national security or public safety reasons.

(5) The Department of Defense will develop measures to prevent the hostile use of GPS and its augmentations to ensure the United States retains a military advantage without unduly disrupting or degrading civilian uses.

(6) This plan reflects the US decision not to proceed with developing a Microwave Landing System (MLS) as the next standard for civil aircraft precision instrument landing guidance. The DOD has implemented MLS technology for some aircraft through mobile services as described in Enclosure F. The Europeans have decided to see how the United States will implement GPS for civil aviation use before terminating their MLS plans.

(7) This plan assumes that the FAA will develop a GPS WAAS that will meet domestic aircraft en route, terminal, non-precision approach and Category 1 precision approach instrument flight needs. The FAA anticipates that Europe and other countries will adopt its WAAS system and provide similar capabilities worldwide.

(8) The FAA plans to develop a GPS LAAS to meet aircraft Categories II and III precision instrument landing needs and to augment certain geographical areas where the satellite-based WAAS may not provide adequate coverage for Category I precision approaches. Other countries may choose to provide the same aircraft navigation capability by using the same, or similar design, once chosen.

b. Current Issues

(1) The United States continues to review GPS accuracies and capabilities provided directly to civil users and to assess their national security implications. For example:

(a) The new PDD on GPS requires the Secretary of Defense, in cooperation with the Secretary of Transportation, the Director of Central Intelligence, and the heads of other departments and agencies, to provide the President with an annual assessment of and recommendation on the continued use of SA, beginning in 2000.

(b) Civil users have expressed an interest in having an additional GPS frequency available to them, to allow direct measurement of ionospheric errors. In the interest of eliminating the growing dependency on the military L2 frequency, the Department of Defense provided, at the request of the DOT, an option to include an additional civil signal in the next production of GPS satellites. This satellite production contract, called Block IIF, was awarded in April 1996. The contract calls for 33 satellites, which are currently scheduled to begin entering into the GPS constellation in the 2001 time frame. Although the desire to add a second civil frequency remains, the method to accomplish this is currently not known technically or contractually. In an effort to establish a strategy, the Department of Defense and DOT have agreed to work together to formulate a plan by March 1998. In the interim, the Department of Defense and DOT have reached an agreement where the characteristics of the L1 and L2 signal structure will not be changed.

(2) The Department of Defense is embarking on several priority programs to protect its military advantage in the use of GPS without unduly disrupting or degrading civilian uses. One of the programs involves the development of a new GPS security device, the Selective Availability and Antispoofing Module (SAASM). The other priority program is titled Navigation Warfare (Navwar). This program includes efforts to reduce the susceptibility of GPS to jamming, while increasing DOD ability to prevent the full benefits of GPS to hostile military users. Included in this development effort is the focus to eliminate the military reliance on the unencrypted civilian signal (on the GPS L1 frequency) in order to acquire the military, encrypted signal.

(3) Civilian and military aircraft require the ability to conduct both non-precision and precision approaches (approaches that provide vertical guidance) to landing. The United States has canceled its plan to develop a civilian MLS and is pursuing GPS augmentations to meet civilian needs. The FAA has defined the accuracy, availability, integrity, and continuity of service capabilities for GPS-based systems needed for civilian instrument landing systems. It has proposed and is developing augmentations to GPS that would have GPS be the sole means of en route, terminal area, and instrument landing guidance. The Department of Defense is studying its PNT capabilities and has not yet finalized how these capabilities will be merged to allow DOD aircraft to conform to the applicable national and international requirements for flight in controlled airspace.

(4) The Under Secretary of Defense and the Vice Chairman of the Joint Chiefs of Staff have tasked the Air Force Director of Operations to take the lead in considering what must be done by the Department of Defense to use the GPS PPS to conduct flight operations in controlled airspace. The focus of this investigation is to provide recommendations on the actions necessary, beginning in FY 98, to implement the operational policies, equipment and/or software modifications, flight operations standards, documentation, procedures, and other system integration and support requirements, to enable DOD aircraft to take off,

fly, and recover to non-precision approach minimums anywhere in the world without reference to ground-based radionavigation aids.

4. Responsibilities. The Under Secretary of Defense for Acquisition and Technology(USD(A&T)) provides overall guidance on matters of PNT research, development, test and engineering, modifications, acquisitions, and use. The USD(A&T) is the chairman of the DOD Pos/Nav Executive Committee, a group of senior officials who provide overall management supervision and decision processes for DOD PNT matters, and the cochair of the new Interagency GPS Executive Board (IGEB) as directed by the PDD. The IGEB is chartered to manage the dual use components of GPS and US GPS augmentations (WAAS, LAAS, DGPS, etc.).

a. The Chairman of the Joint Chiefs of Staff serves as the principal spokesman for DOD PNT operational matters. These functions include:

(1) Developing joint PNT operational doctrine and tactics.

(2) Reviewing Service budgets to ensure satisfaction of validated PNT requirements, to avoid duplication of effort, and to prevent expenditure of funds on systems scheduled to be phased out.

(3) Promoting standardization, interoperability, and compatibility to fulfill common requirements.

(4) Coordinating PNT matters affecting NATO and individual nations.

(5) Providing direction and inputs for the development of a navigation systems architecture that describes operating concepts, system developments, replacement plans, and alternatives for satisfying validated requirements.

(6) Providing representation to the DOD Pos/Nav Executive Committee, the Pos/Nav Working Group, and the IGEB.

(7) Reviewing and publishing the CJCS MPNTP, integrating the revision with the budget process, and FRP.

b. Within their respective commands, CINCs perform functions of the same general nature as those of the Chairman of the Joint Chiefs of Staff, including planning for the operational employment of PNT systems in war and contingency plans. CINCs may develop PNT requirements in support of contingency plans and CJCS-directed or CJCS-coordinated exercises that require not only their own but also other PNT resources. CINCs are also responsible for reviewing the CJCS MPNTP, suggesting changes, establishing requirements, and implementing the plan.

c. USCINCSPACE will operate the GPS as described in reference f. The PPS will be operated in accordance with reference e. The decision to alter SPS performance so that an error level greater than 100 meters is provided will be made by the National Command Authorities (NCA) after recommendation by the CJCS following a request by a CINC. USCINCSPACE will develop means to notify, as rapidly as possible, the US Coast Guard (USCG)

Navigation Center and the FAA NOTAM Office of all SPS GPS issues which may affect the civil user community.

d. The Military Departments are responsible for participating in the development, approval, and dissemination of the CJCS MPNTP and for implementation.

e. The US Navy, through the US Naval Observatory, is responsible for establishing, maintaining, and coordinating the astronomical reference frame(s) for celestial navigation and orientation of space systems. Requirements for precise time and time interval (PTTI) should be identified to the DOD PTTI managers identified in Enclosure J.

f. The Secretary of Transportation, under Public Law 89- 670, is responsible for navigation matters within the DOT and, in coordination with the Department of Defense, develops the FRP. Public Law 85-726 authorizes the Administrator of the FAA to develop and implement systems to meet the needs for safe, efficient navigation and traffic control of all civil and military aviation, except for those needs peculiar to air warfare and primarily within the purview of the Military Services. Federal law requires extensive coordination between FAA and the Department of Defense. Title 14, United States Code, sections 2 and 81, directs USCG to provide aids to maritime and air navigation for civil and military users. USCG is specifically authorized to establish, maintain, and operate electronic, aural, and visual aids to navigation required to serve the needs of the Armed Forces of the United States peculiar to warfare and primarily of military concern as determined by the Secretary of Defense. The USCG and the Joint Staff coordinate to meet this responsibility. USCG operates all US-owned LORAN transmitters. Also, USCG has been designated the lead DOT agency for Civil GPS Service operations, which include near-real-time Operational Status Capability (OPSCAP) reporting to civil users and civil distribution of precise GPS satellite ephemerides. The US Coast Guard Radionavigation Program Manager is the Office of Aids to Navigation, Commandant (G-OPN), and the operational point of contact is located at the US Coast Guard Navigation Center in Alexandria, Virginia.

g. The Department of Commerce, through jurisdiction of the National Oceanic and Atmospheric Administration (NOAA), provides navigation support resources to the Department of Defense. That support is effected by regulatory agreements governing both peacetime and wartime operations.

h. The National Imagery and Mapping Agency (NIMA) is responsible for mapping, charting, and geodesy (MC&G) support to DOD navigation systems. That support includes charts, digital terrain elevation data, digital feature analysis data, digital hydrographic chart data, point-positioning data bases, geodetic surveys, the World Geodetic System 1984 (WGS 84), and associated tables that are compatible with and meet the accuracy objectives approved by the Chairman of the Joint Chiefs of Staff. MC&G support also includes geodetic positioning of transmitters for electronic systems and tracking stations for satellite systems, maintenance of GPS fixed site operations, and generation and distribution of GPS precise ephemeredes. NIMA acts as the primary point of contact with the civil community on matters relating to geodetic uses of DOD navigation systems and provides calibration support for certain airborne navigation systems.

i. NASA cooperates with the Department of Defense in the development of PNT systems and associated avionics.

j. NSA is responsible for the development of cryptographic devices and techniques used to deny the unauthorized use of PNT systems information. Operational concepts and plans that establish PNT security requirements and procedures will be approved by the Joint Staff.

k. The March 1996 GPS PDD established a permanent IGEB, jointly chaired by the USD(A&T) and the Assistant Secretary of Transportation for Transportation Policy (OST/P-1). The IGEB is chartered to manage the dual use features of GPS and USG augmentations consistent with national policy, to support and enhance US economic competitiveness and productivity while protecting national security and foreign policy interests. Representatives from the Department of State, Department of Agriculture, Department of Commerce, Department of Interior, National Aeronautics and Space Administration, and the Chairman of the Joint Chiefs of Staff are members of the IGEB.

l. The DOD Pos/Nav Executive Committee assists the USD(A&T) in the review of all DOD PNT programs. The purpose of the review is to minimize duplication of effort, to effect economies wherever prudent and appropriate, and to make recommendations to the Secretary of Defense, in coordination with the Chairman of the Joint Chiefs of Staff and the Services, on cost-avoidance or phaseout of PNT systems.

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ENCLOSURE B

POSITIONING, NAVIGATION, AND TIMING POLICY

1. General Requirements Policy

a. PNT System Characteristics. Military forces must be prepared to conduct wartime operations in the air, on and under the sea, on land, and in space. Additionally, the force structure must be able to communicate, and precise clock time and frequency synchronization among platforms is critical to achieving this capability. During peacetime, military platforms must have equipment to conform to applicable national and international rules of the road in controlled airspace, on the high seas, and in coastal and inland areas. DOD PNT users may use US civil systems for peacetime operations where their use does not jeopardize DOD ability to carry out its military mission. Use of foreign PNT sources that are not provided by countries with defense arrangements with the Department of Defense are prohibited. The preceding prohibitions do not apply to ships and aircraft in peacetime navigation scenarios as long as the system(s) in use are International Maritime Organization or ICAO recognized systems, respectively. Commercially provided PNT sources are not authorized for DOD operations. The ideal PNT system that supports military operations should have the following essential characteristics:

(1) Worldwide coverage.

(2) User-passive.

(3) Capable of denying and degrading use by adversaries.

(4) Able to support an unlimited number of users.

(5) Resistant to countermeasures. Systems should be as survivable and endurable as the forces and weapon systems they support including hostile attack, electromagnetic pulse (EMP), and natural disturbances.

(6) Effective, real-time response.

(7) Interoperable among Services, allies, and friendly forces.

(8) Free from frequency allocation problems.

(9) Common grid or map datum reference for all users.

(10) Accuracy that is neither degraded by changes in altitude for air and land forces nor by time of year or day.

(11) Accurate when the user is in high-"G" or other violent maneuvers.

(12) Maintainable by personnel at the user's location.

(13) Self-contained.

(14) Continuously available for positioning information with integrity and fault detection and exclusion.

(15) Provides method for ensuring system integrity that provides an annunciation system to alert users when not to use the system for navigation.

(16) Continuously reliable for all PNT purposes.

b. Policy Guidance. No single system or combination of systems currently available has all of these characteristics. There is no single system that provides a common grid for all users, is passive, self-contained, and yields precise accuracy on a worldwide basis. The nature of military operations requires that essential PNT services be available with the highest possible confidence that these services will meet or exceed mission requirements. Availability of essential PNT services requires that military operators use a mix of self-contained, self-initiated, and external-referenced systems. Services will develop systems that will allow these independent systems to provide synergistic benefit and graceful degradation through data integration. Although general military requirements remain fairly constant, continuous review is required because of the impact of new technology, weapon system modifications, the dynamics of national policy interests, and the nonmilitary environment to which the military must respond.

2. Operational Survivability Utility Requirements Policy. PNT systems must be as survivable and enduring as the forces and weapon systems they are designed to support. Terrestrial-based systems (TACAN, MLS, ILS, etc.) must employ physical security measures that reduce vulnerability to sabotage or terrorist attack. Rapid reconstitution plans, including plans for replacement transmitters, use of rugged construction techniques, and conventional and nuclear hardening, should be considered. Space-based systems must be hardened against EMP to at least the same level as the forces the system supports, in both the space and control segments. Transmission and reception techniques to prevent jamming and other interference must be employed. Additionally, methods need to be employed to prevent hostile exploitation of PNT systems and to deny use of such systems to military adversaries or other combatants. Physical security measures must be in place to minimize the impact of destruction or incapacity of satellite ground control segments.

3. Aviation Requirements Policy. Aircraft must be equipped with suitable instruments and navigation equipment appropriate to the routes to be flown. The FAA issues Technical Standard Orders (TSOs) that prescribe minimum performance standards for navigation equipment used by the civil aviation community in the National Airspace System (NAS). The International Civil Aviation Organization (ICAO) issues Standards and Recommended Practices (SARPS) for international civil aviation. The development of minimum performance standards for military users is the responsibility of the Services. These military standards must: conform with civil airspace required navigation performance (RNP) standards, prevent violation of civil air traffic clearances, ensure safe separation of military and civil air traffic, and ensure military aircraft achieve an "Equivalent Level of Safety." While meeting the ICAO SARPS is an essential deployment requirement, military combat, and combat support

aircraft must have PNT capabilities designed to operate in a combat or stressed environment where civil PNT services are likely to be jammed or severely limited.

4. C4ISR Systems Timing Policy. C4 systems timing shall be developed and implemented consistent with paragraphs 1 and 2 of this enclosure. For example, C4 systems which rely on GPS for timing shall first use only secure PPS receivers, and, second, incorporate the capability to operate without continuous GPS availability or integrity.

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ENCLOSURE C

POSITIONING, NAVIGATION, AND TIMING SYSTEM ARCHITECTURE

1. General. The PNT system architecture, summarized in this enclosure and in phasein and phaseout schedules, is based on the need for accuracy, integrity, dependability, coordination of forces, and the denial of accuracy to enemies. To the maximum extent feasible, consistent with needs and economy, users should be self-sufficient. This self-sufficiency dictates the use of inertial navigation systems (INS), celestial navigation systems, and various types of radar and sonar or electro-optical sensors. To ensure coordination of forces, there should be a common set of geographic coordinates or common grid. For the coordination of forces to an uncharted or moving reference, a relative positioning system may be required. All of the requirements discussed in Enclosure A cannot be satisfied, at present or in the foreseeable future, by a single system. A navigation concept based on an advanced satellite system with global precision coverage, integrated with supplementary self-contained or self-initiated systems, will be the most effective combination of systems. That architecture is designed to satisfy current and future operational requirements, to accept new or improved systems as they develop, and to eliminate duplicative systems.

2. Planning Guidance. The latest Federal Radionavigation Plan contains US policy and plans for the future civil/military radionavigation systems mix. The following is a synopsis of this statement:

a. LORAN-C. The USCG operates LORAN-C transmitters that provide coverage of the continental United States (CONUS) and contiguous waters. The United States plans to terminate Loran-C operations on 31 December 2000.

b. DGPS. THE USCG has developed a maritime DGPS service which provides coastal coverage of CONUS, the Great Lakes, Puerto Rico, portions of Alaska and Hawaii, and portions of the Mississippi River Basin. The inland portion of this system was developed in partnership with the Army Corps. of Engineers. Maritime DGPS uses fixed GPS reference stations, which broadcast pseudo-range corrections using radiobeacons. The USCG system currently consists of 55 sites. The system has been recognized by the International Maritime Organization (IMO), and it is estimated that some 22 countries with maritime interests are fielding services which comply with the standards developed by the Radio Technical Commission or Maritime Services (RTCM). In addition to providing corrections to eliminate the effects of Selective Availability, the system provides civil users with real-time GPS integrity data.

c. VOR/DME. VOR/DME is the international civil standard short-range aviation navigation system. The phaseout of VOR/DME from the NAS is expected to begin in 2005 and to be complete by 2010. This phaseout schedule is directly dependent on the commissioning dates of GPS/WAAS. The FAA is examining the possibility of retaining a network of a reduced number of VOR/DME facilities beyond 2010 that could serve as a complement to GPS-based primary navigation.

d. TACAN. The DOD requirement for and use of land-based TACAN will terminate when aircraft are properly integrated with GPS and when it is determined by the Department of Defense that GPS has achieved a capability to operate, on a worldwide basis, as the only external radionavigation system in aircraft avionics suites, which provides the required level of navigation performance (accuracy, integrity, availability, and continuity of service) for all phases of flight except precision approach to landing. The target date to begin TACAN phaseout is 2005. The requirement for shipboard TACAN will continue until a suitable replacement is operational.

e. Precision Landing Systems

(1) The Instrument Landing System (ILS) serves as the civil standard for Category I precision aircraft approaches until replaced by a GPS-based service. WAAS Category I precision approach service is expected to reach IOC in 2000, and the system is anticipated to be fully operational in 2002. Dual ILS and WAAS service will be provided for a transitional period to allow users to equip with WAAS receivers and to be comfortable with its service. The phaseout of Category I ILS is then expected to begin in 2005 and to be complete by 2010.

(2) The date when GPS-based Category II/III approaches will become available for public use is uncertain. Accordingly, the existing Category II/III ILS systems will be sustained, and ILS technology will be required for upgrading the capability of a system (Category I to Category II to Category III) and for new establishments.

(3) In April 1995, the ICAO endorsed the Global Navigation Satellite System (GNSS) as a candidate system for international use and canceled the requirement for international runways to be equipped with the MLS by 1 January 1998. ICAO also extended the ILS protection date to 1 January 2010. The United States will continue to promote the international acceptance and implementation of GPS for navigation in all phases of flight.

(4) The FAA has terminated the development of MLS based on favorable GPS test results and budgetary constraints. The United States does not anticipate installing additional MLS equipment in the NAS, but could purchase systems on the open market for Category II/III operations if the need should arise in the future. The phaseout of Category I MLS is expected to begin in 2005 and to be complete in 2010.

f. GPS. GPS is planned to become the primary radionavigation system for the Department of Defense. GPS will be used to satisfy most positioning, velocity, and timing requirements including aircraft en route navigation, and nonprecision approach operations within the NAS, ICAO airspace, and military theaters of operation. With augmentation, GPS may also be determined to be suitable for precision approach to landing and maneuvering in restricted waters (see subparagraph 3b below).

g. Nondirectional Beacons. The DOD requirement for and use of land-based nondirectional aviation beacons will terminate when the Department of Defense approves GPS for use as a nonprecision approach aid.

h. Wide Area Augmentation Systems. The FAA is currently developing the Wide Area Augmentation System (WAAS) to augment civil GPS service. The FAA plans to use the WAAS/GPS combination to replace civil VOR/DMEs and Category I ILS service in NAS. The Department of Defense currently has no validated requirement to use WAAS to augment its GPS service. The Department of Defense is developing requirements for future use of a WAAS in the noncombat environment. As laid out in reference c, the IOC for WAAS is projected to be in 1999, followed by an FOC estimate date of 2001.

i. Local Area Augmentation Systems. The FAA is developing standards for a LAAS to support replacement of Category II/III ILS. LAAS is not currently funded for procurement as a federal radionavigation system. Also, the Department of Defense has no validated requirements to use LAAS at this time. Future requirements for LAAS in certain applications will be evaluated on a case-by-case basis (see subparagraph 3b below).

3. Projected PNT System Plan Actions. The following paragraphs summarize the actions that make up the PNT system plan:

a. Flight in Controlled Airspace Using GPS. The Under Secretary of Defense (Acquisition and Technology) acting in his role as Chairman of the DOD Pos/Nav Executive Committee and the Vice Chairman of the Joint Chiefs of Staff have requested the Air Force Director of Operations take the lead, through the GPS Phasein Steering Committee (PISC), in considering what must be done by the Department of Defense to use the GPS PPS to conduct flight operations in controlled airspace. The Steering Committee was chartered to determine the actions necessary, beginning in FY 1998, to implement the operational policies, equipment and/or software modifications, flight operations standards, documentation, procedures, and other system integration and support requirements, to enable DOD aircraft to take off, fly, and recover to nonprecision approach minimums anywhere in the world without reference to ground-based radionavigation aids. Global Air Traffic Management (GATM) is the USAF's effort to ensure DOD aircraft comply with new FAA/ICAO communications, navigation, surveillance and air traffic management requirements and will involve significant investment by the Department of Defense to properly equip aircraft. The Department of Defense must introduce the needed technology to comply with the new FAA/ICAO requirements in order to preserve worldwide deployment capability, avoid air traffic control delays, enhance airspace management capability, ensure safe separation of military and civil aircraft, and minimize cost. Meeting GATM requirements through an optimum mix of PNT technologies focused on satisfying peacetime requirements while preserving wartime capabilities in DOD aircraft is an absolute requirement.

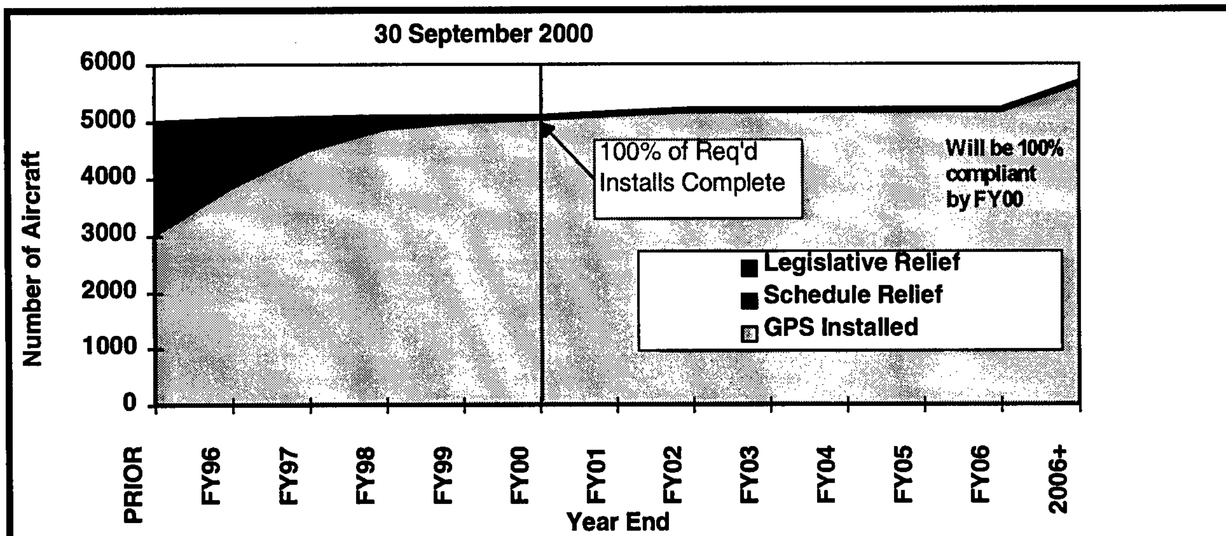
b. Aircraft Precision Approach. The DOD has initiated a Joint Precision Approach and Landing System (JPALS) program to determine its future precision approach requirements and systems. The JPALS Phase 0 Concept Exploration will include an analysis of alternatives to address near- and long-term precision approach and landing system solutions. ILS, MLS, PAR, DGPS (P/Y-code), and multimode receivers will be among the materiel solutions considered. A Milestone I decision is expected in 1998. The JPALS recommended alternatives will dictate DOD precision approach system decommissioning dates as well as funding requirements. Existing precision approach systems must be sustained until these dates.

c. TACAN Replacement for Ships and Aircraft Operating with the Fleet. GPS augmented by differential or relative techniques appear to be a promising candidate for sea-based TACAN replacement.

d. C-SCAN/Marine Remote Area Approach and Landing System Replacement (MRAALS). C-SCAN and MRAALS are microwave landing systems used exclusively by the Navy and Marine Corps for shipboard, expeditionary airfield, and helicopter applications. They will continue until a replacement is operational.

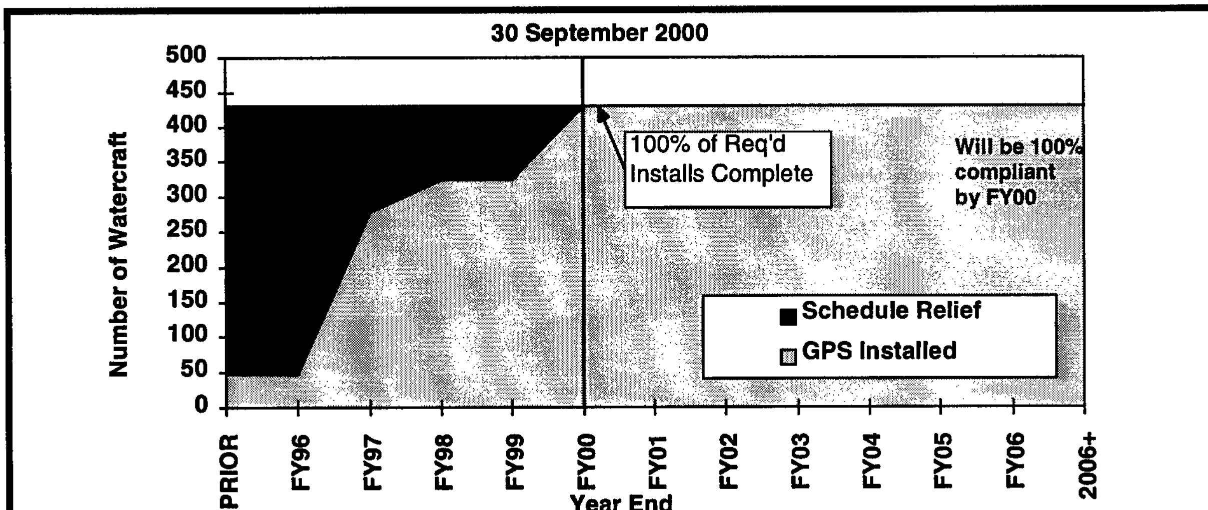
e. Precision Approach Radar (PAR). The requirement for PAR remains for many aircraft not equipped with ILS. PAR is also still the recognized NATO standard system. The Joint Precision Approach and Landing System study will review PAR sustainment issues and transition plans. Until a replacement for ILS is operational and the JPALS effort recommendations are implemented, the requirement for PAR will remain.

4. GPS Phasein Plans. Congressional Record, H9194 of 10 November 1993, placed limitations on procurement of system not GPS equipped. In accordance with this mandate, termed GPS 2000, after 30 September 2000, funds may not be obligated to modify or procure any DOD aircraft, ship, armored vehicle, or indirect-fire weapon system that is not equipped with a GPS receiver. Equipping all effective DOD platforms is occurring at varying rates. The following charts show GPS user equipment installation progress for DOD platforms as of the publication of this document. Services' and Defense agencies' are additionally advised that as of the date of this plan, the various legislative reliefs reflected in the following tables have not been fully coordinated with Congress.



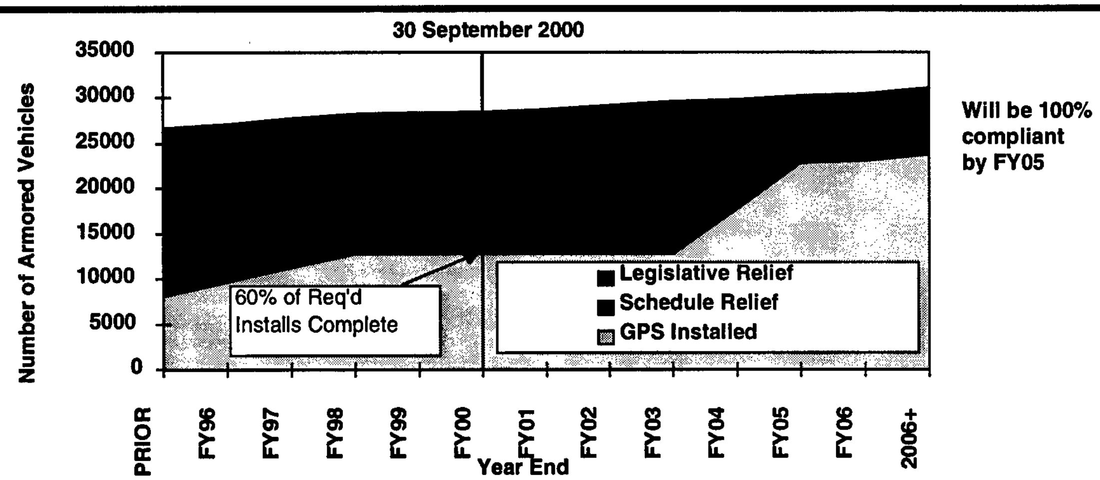
Legislative Relief (92)	Schedule Relief (0)	No Reqt for Future Mod (0)
TH-67 (92) (VFR-only Trainer)	None	None

TABLE C-1. GPS USER EQUIPMENT INSTALLATION PROGRESS
USA AIRCRAFT



Legislative Relief (0)	Schedule Relief (0)	No Reqt for Future Mod (0)
None	None	None

TABLE C-2. GPS USER EQUIPMENT INSTALLATION PROGRESS
USA WATERCRAFT



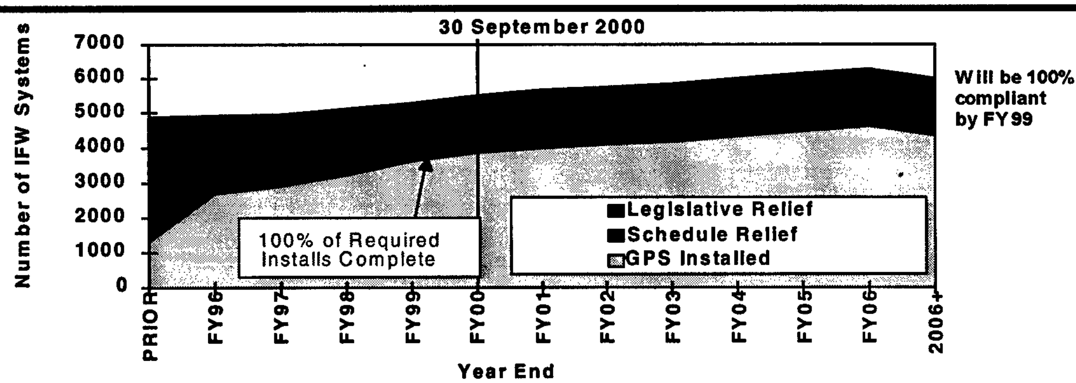
Legislative Relief (7,336)
AWR* vehicles (4,336) (Vehicles in storage -- no GPS requirement; when deployed, units will bring hand-held receivers)
Logistical/support base vehicles (3,000) (No combat mission requirement)

Schedule Relief (9,613)
FP-4** vehicles (9,613) (Will be equipped in FY03-05 when PLGR cascaded to FP-4)

No Reqt for Future Mod (0)
None

* AWR - Army War Reserve
**FP-4 - Force Package - 4

TABLE C-3. GPS USER EQUIPMENT INSTALLATION PROGRESS
USA ARMORED VEHICLES

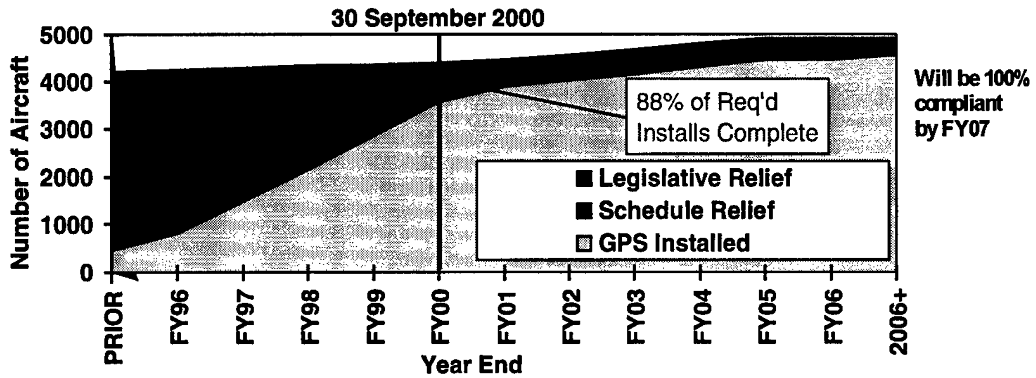


Legislative Relief (1,654)
Towed Artillery Systems (1,383) (Units have hand-held PLGRs to survey firing positions -- not reqd for each weapon system)
Self-propelled Artillery Systems (271) (Vehicles in storage -- no GPS requirement; when deployed, units will bring hand-held receivers)

Schedule Relief (0)
None

No Reqt for Future Mod (0)
None

TABLE C-4. GPS USER EQUIPMENT INSTALLATION PROGRESS
USA INDIRECT FIRE WEAPONS (IFW)



Legislative Relief (135)
T-2C (89) (No Mission Requirement)
TH-57B (46) (No Mission Requirement)

Schedule Relief (455)
AH-1W (40) (Maj Avionics Upgrade) (FY02)
HH-1N (25) (Funding Priorities) (FY06)
TE-2C (2) (Maj Avionics Upgrade) (FY06)
F-5E/F (33) (Funding Priorities) (FY02)
F/A-18A/B (109) (Funding Priorities) (FY07)
F/A-18C/D (95) (Funding Priorities) (FY01)
TC-18F (2) (Funding Priorities) (FY06)
T-34C (11) (Funding Priorities) (FY01)
T-39N (13) (Maj Avionics Upgrade) (FY05)
T-45A (71) (Maj Avionics Upgrade) (FY07)
SH-60B (22) (Maj Avionics Upgrade) (FY02)
KC-130 (32) (Funding Priorities) (FY03)

No Reqt for Future Mod (289)
E-2C (24) (Retire by FY03)
F-14A (105) (Retire by FY04)
T-34C (82) (Retire by FY05)
CH-46D (26) (Retire by FY05)
HH-46D (39) (Retire by FY05)
UH-46D (13) (Retire by FY04)

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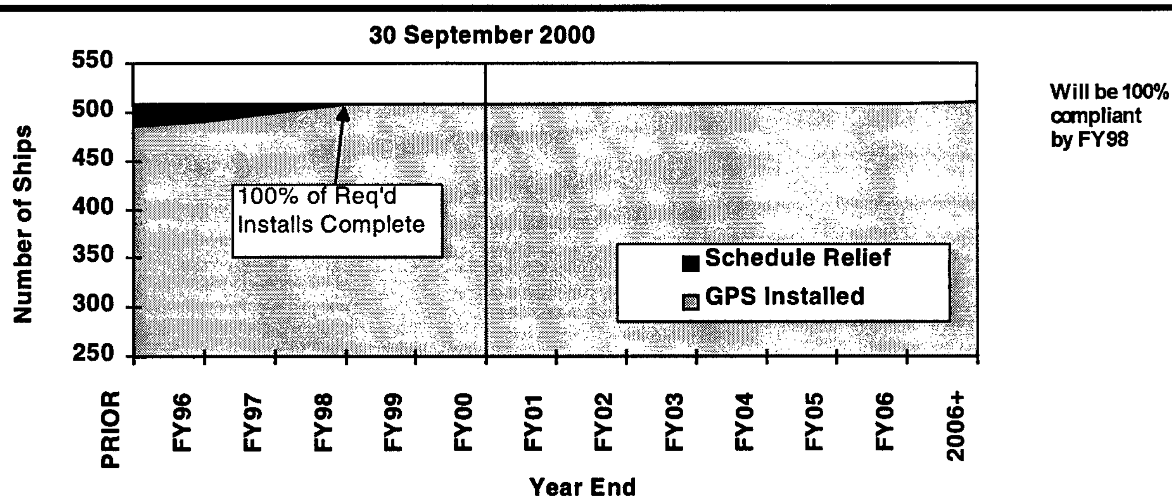
TABLE C-5. GPS USER EQUIPMENT INSTALLATION PROGRESS
USN, USMC, AND USCG AIRCRAFT

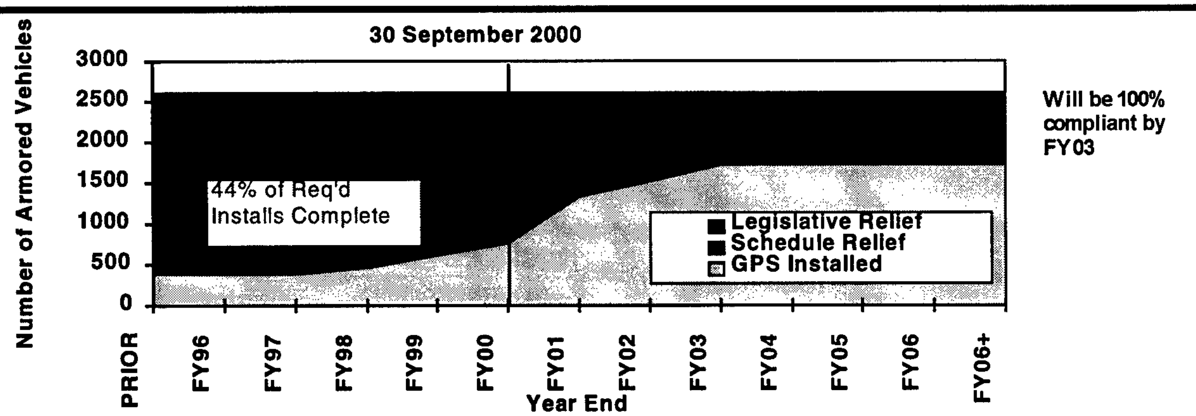


Legislative Relief (0)
None

Schedule Relief (0)
None

No Reqt for Future Mod (0)
None

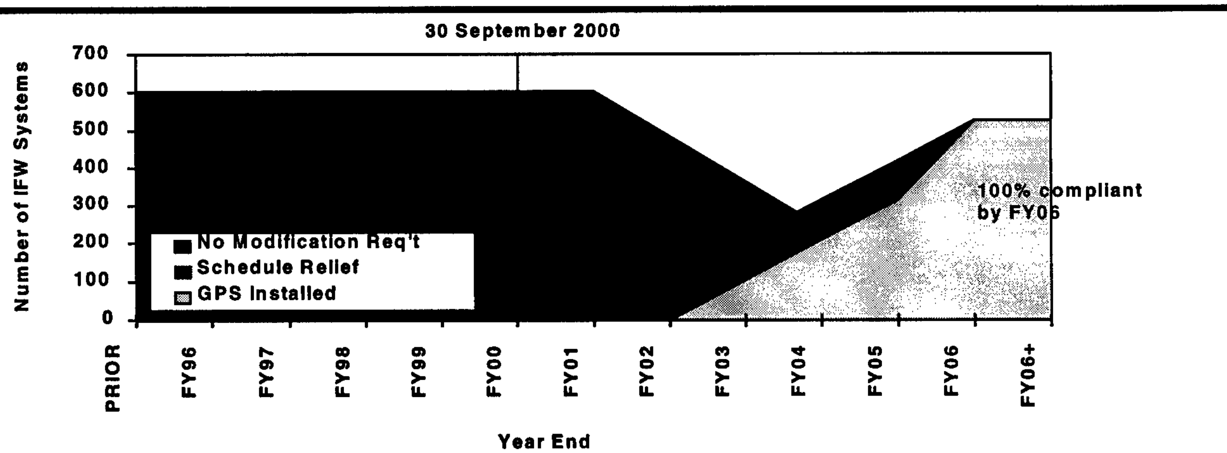
TABLE C-6. GPS USER EQUIPMENT INSTALLATION PROGRESS
USN, USMC, AND USCG SHIPS



Legislative Relief (879)			Schedule Relief (957)	No Reqt for Future Mod (0)
M1A1	(174)	(Part of MPF*)	LAV (118) (Completion with PLGR & DACT** procurement) (FY01)	None
	(87)	(Tank retriever)	AAV (739) (Completion with PLGR & DACT procurement) (FY03)	
	(37)	(Bridge launcher)		
LAV	(63)	(Part of MPF)		
	(139)	(Non-shooter)		
AAV	(315)	(Part of MPF)		
	(64)	(Logistic/support)		

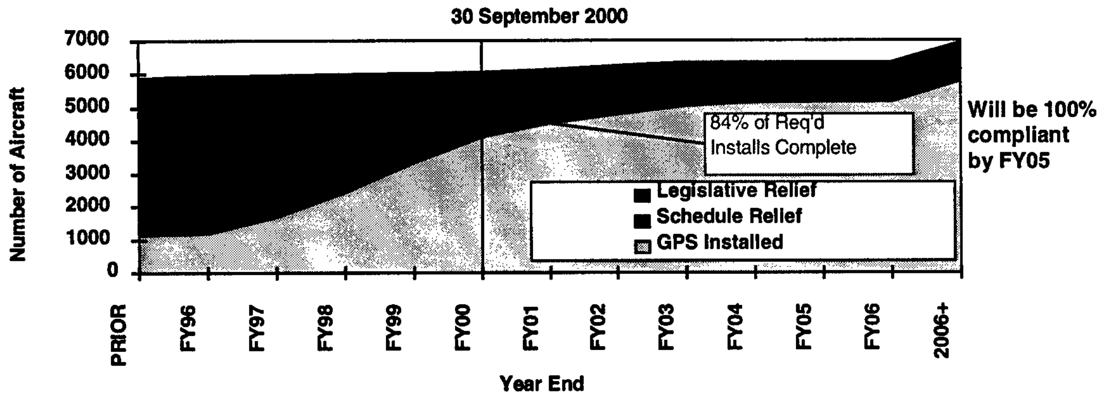
* MPF - Maritime Preposition Force
** DACT - Digital Automated Communications Terminal

TABLE C-7. GPS USER EQUIPMENT INSTALLATION PROGRESS USMC ARMORED VEHICLES



Legislative Relief (105)	Schedule Relief (0)	No Reqt for Future Mod (603)
LW155 (105) (Production of 526 total begins FY02; GPS product improvement starts FY03) Artillery firing units have PLGR to assist in site survey		M198 (Howitzer) (603) (Replaced by LW155 beginning FY02; PLGRs currently used in artillery site survey)

TABLE C-8. GPS USER EQUIPMENT INSTALLATION PROGRESS USMC INDIRECT FIRE WEAPONS

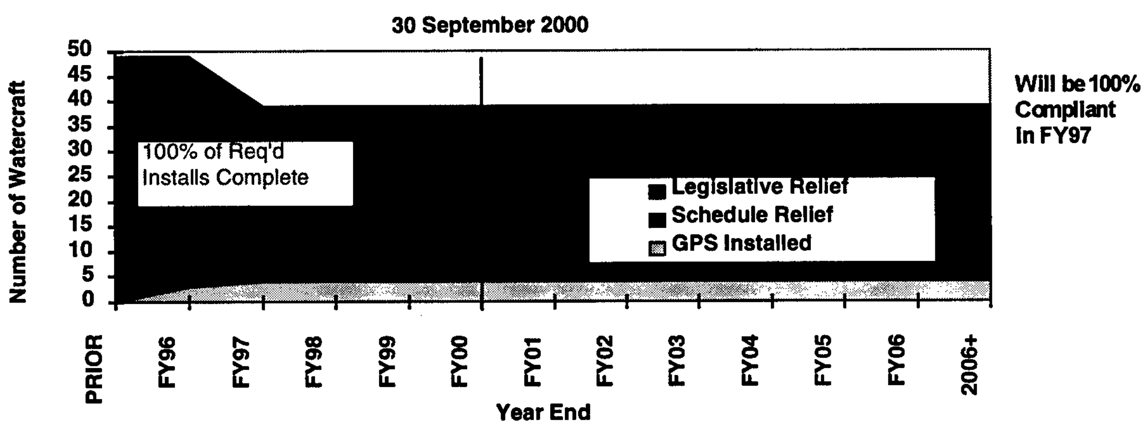


Legislative Relief (1,148)		
F-15A-D	(486)	(No near-term operational need for GPS)
F-15A-D	(44)	(Retirement)
T-37	(473)	(Retirement)
T-3	(110)	(VFR-only Trainer)
TG-3,4,9,10	(30)	(Gliders, No Reqt)
VC-137	(5)	(Retirement)

Schedule Relief (779)		
F-15E	(30)	(GPS Equipment Change) (FY01)
F-16 B30	(124)	(Funds Pulled/Restored) (FY01)
A/OA-10	(200)	(GPS Equipment Change) (FY03)
T-38	(425)	(Major Avionics Upgrade) (FY05)

No Reqt for Future Mod (0)
None

TABLE C-9. GPS USER EQUIPMENT INSTALLATION PROGRESS
USAF AIRCRAFT



Legislative Relief (34)
Watercraft (34) (No requirement for GPS – Small craft, good weather, close to shore)

Schedule Relief (0)
None

No Reqt for Future Mod (0)
None

TABLE C-10. GPS USER EQUIPMENT INSTALLATION PROGRESS
USAF WATERCRAFT

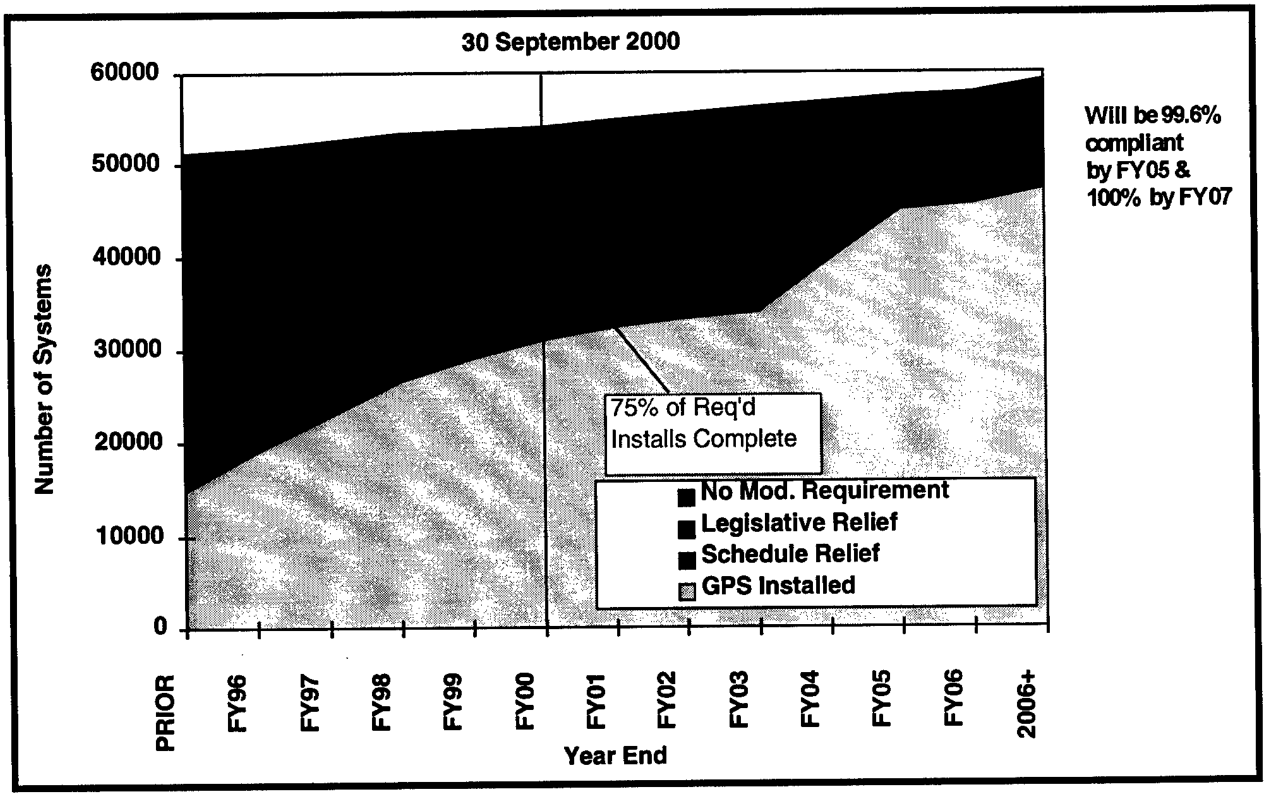


TABLE C-11. GPS USER EQUIPMENT INSTALLATION PROGRESS
DOD ROLL-UP

ENCLOSURE D

GPS OPERATIONS AND SECURITY POLICY

1. Summary. The Department of Defense intends to operate the GPS to provide a military advantage for the United States and its allies over any potential adversary. At the same time, the Standard Positioning Service component of GPS will be available to all users, for peaceful purposes, with no direct fee. In providing this service, the Department of Defense will maintain a 24 satellite constellation.

a. The Department of Defense will maintain the military advantage afforded to the United States and its allies through GPS by limiting the availability of the full capability of GPS. It will intentionally degrade the GPS capability available to all users and take measures necessary to defeat hostile military attempts to use GPS. DOD, allied, and friendly foreign GPS users will use cryptographic equipment to ensure exclusive use of the full capability of GPS.

b. Normally, the Department of Defense will provide to all GPS users a SPS with a horizontal accuracy of 100 meters or better (95 percent probability). In March 1996 the White House issued Presidential Directive NSTC-6, which announced that the United States intends to discontinue the use of SA within a decade (by 2006). Beginning in 2000, the President will make an annual determination on continued use of SA. To support this determination, the Secretary of Defense, in cooperation with the Secretary of Transportation, the Director of Central Intelligence, and heads of other Federal departments and agencies, shall make an assessment and recommendation on continued SA use.

2. System Operation and Definitions. The GPS provides two levels of service - a SPS and a PPS. GPS satellites broadcast data on two frequencies: 1575.42 MHz (L1)and 1227.6 MHz (L2). The Department of Defense has the capability to deny the full accuracy of the basic GPS to unauthorized users through the use of degradation techniques and cryptography.

a. The SPS consists of signals transmitted on the GPS L1 frequency that are modulated by the Coarse/Acquisition (C/A) code and use the unencrypted portion of the 50 Hz GPS navigation data message.

b. The PPS consists of signals transmitted on both the GPS L1 and L2 frequencies. The PPS uses information transmitted on the GPS L1 frequency as modulated by the C/A and military Precise codes (either P code or the encrypted Y code if Anti-Spoofing (A-S) is activated), and the 50Hz navigation data message, including the encrypted portion. The PPS also uses information transmitted on the GPS L2 frequency as modulated by the military code and the 50Hz navigation data message, including an encrypted portion. The C/A code is not available on the L2 frequency. The Department of Defense controls access to the PPS through cryptography.

3. Selective Availability (SA) and Anti-Spoofing (A-S). Two distinct techniques, SA and A-S, are used to prevent unauthorized use or exploitation of the PPS.

SA is the intentional alteration and degradation of the accuracy of the positioning and timing data. SA is applied to both the C/A and the P Code GPS navigation data messages. A-S is independent of SA and is designed to protect against spoofing (imitation) and unauthorized use by encrypting the P code. The encrypted version of the P code is called the Y code.

4. Operating Modes. GPS satellites have the capability to be operated in four different modes. They are:

a. Open Mode. SA is "zero" and A-S is "off." Satellite navigation data, clock, and tracking codes (C/A and P) are neither altered nor encrypted. Any properly designed receiver will be able to obtain full system accuracy.

b. SA Only Mode. SA is "active" and A-S is "off." Satellite ephemeris and/or clock performance are altered to reduce accuracy. PPS receivers must be properly keyed to compensate for the effects of SA. Un-keyed receivers will be able to obtain SPS. The GPS P code is not encrypted.

c. A-S Only Mode. SA is "zero" and A-S is "on." Satellite ephemeris and clock performance are not degraded. The P code is encrypted to create the Y code to protect against spoofing and unauthorized use; the C/A code is not encrypted. A PPS receiver must be properly keyed to process the Y code and minimize the risk of spoofing. An un-keyed PPS receiver will be able to obtain non-degraded SPS.

d. SA/A-S Mode. SA is "active" and A-S is "on." All PPS security techniques are employed. PPS receivers must be properly keyed to obtain PPS and to minimize the risk of being spoofed. Un-keyed receivers will be limited to SPS. THIS IS THE NORMAL GPS OPERATING MODE.

5. Operating Policy. The Department of Defense will operate the GPS by implementing the SA/A-S features described above. These features prevent unauthorized direct access to GPS military accuracy. They also prevent the disruption to, or denial of, GPS access by spoofing or signal imitation. They are intended to make the military exploitation of GPS more difficult for unauthorized users who would use GPS to enhance military performance either against the United States or against some third party. The Department of Defense also intends to deny access to the GPS C/A code and to SPS-based signals by any adversary or in any local area in which a GPS-derived threat to US, allied, or friendly forces exists. In the year 2000 an annual decision regarding SA will be made by the President as described in subparagraph 1b.

6. Procedures for Altering S/A or A-S. A military request to change the GPS operating mode or alter the SPS accuracy level will originate with a combatant commander. It will be addressed to the Chairman of the Joint Chiefs of Staff and include the Secretary of Defense and USCINCSPACE as an information addressee. A decision to degrade SPS accuracy (greater than 100 meters-95 percent) or change the GPS operating mode must be approved by the National Command Authorities. If time and circumstances permit, the Department of Defense will consult with the Secretary of Transportation. Civil users will be notified via the Notice to Airmen (NOTAM) and Notice to Mariners systems. DOD agencies will forward requests for operating mode changes to the

Chairman of the Joint Chiefs of Staff via the Joint Staff in peacetime scenarios with a minimum of 90 days advance. Defense agencies should send information copies of these requests to the Under Secretary of Defense for Acquisition and Technology, the Assistant Secretary for Transportation (Policy), and USCINCSPACE. Non-DOD agencies will forward requests for SA/A-S status changes to the Assistant Secretary for Transportation (Policy). In peacetime scenarios, USSPACECOM will ensure a minimum of 30 days advance notice of GPS operational mode changes is given to all users. Sixty days advance notice will be the goal.

7. SPS Policy

a. SPS Capabilities. The SPS is officially defined in the SPS Signal Specification. Currently the SPS provides at least 100 meters horizontal positioning accuracy (95 percent probability), 300 meters horizontal (99.99 percent probability), and 156 meters vertical positioning accuracy (95 percent). It also will provide a timing accuracy within 340 nanoseconds (95 percent) of Coordinated Universal Time (UTC).

b. SPS Operations. During routine operations, the Department of Defense will provide the Coast Guard Navigation Center and the FAA NOTAM system at least 48-hours advance notice of any planned disruption of the SPS. A disruption is defined as a period in which the GPS is not capable of meeting minimum SPS standards as defined in the SPS Signal Specification. The Department of Defense will advise the Coast Guard and the FAA of any unplanned service disruptions resulting from system malfunctions or unscheduled maintenance as they become known.

8. PPS Policy. The PPS was designed primarily for US military use, and the Department of Defense will control access to the PPS through cryptography. PPS receivers require cryptographic functions to allow receiving the encrypted P (Y) code and decrypting portions of the navigation message that compensate for the effects of Selective Availability. Any PPS receiver lacking the proper cryptographic material (e.g., crypto keys) will be designed to operate in the SPS mode (fallback mode). An SPS receiver will not contain the cryptography functions. DOD GPS users with combat, combat support, or combat service support missions must acquire and use PPS-capable GPS receivers. The United States will enter into special arrangements with military and civil users of allied and friendly governments to allow them use of the PPS. PPS release will be subject to the criteria in Chairman, Joint Chiefs of Staff, Instruction (CJCSI) 6510.01A, "Defensive Information Warfare Implementation."

9. Timing Policy. The time transfer capability of GPS is one of several weapon system enhancement functions that the Department of Defense will protect. The Department of Defense will routinely degrade full GPS time transfer capability. DOD precise time and time transfer users, particularly those who require support for defense communications systems, will acquire and use GPS PPS receivers.

10. PPS Users. There are two categories of PPS users. The first category includes those who are automatically authorized use of the service. The second category includes those that must meet certain additional requirements prior to authorization:

a. Automatically Authorized PPS Users. This category includes: (1) all DOD components and (2) the federal departments, administrations, and agencies of the USG.

b. Other PPS Users. This category includes the following user groups who must negotiate security agreements prior to receipt of crypto-capable user equipment, crypto keys and associated devices: (1) allied and friendly military forces and (2) the federal or central governments of allied and friendly countries. Foreign nonmilitary use must be sponsored by their MOD.

11. Allied and Friendly PPS Users. The following countries have been authorized access:

Australia	Japan
Belgium	Luxembourg
Canada	Netherlands
Denmark	New Zealand
Finland	Norway
France	Portugal
Greece	South Korea
Germany	Spain
Iceland	Switzerland
Israel	Turkey
Italy	United Kingdom
Kuwait	Saudi Arabia
Singapore	

12. Cryptographic Measures. There are two types of operational crypto keys available to authorized users--the Group Unique Variable (GUV) and the Cryptovariable Weekly (CVW). The cryptoperiod or period of validity for GUVs will be directed by the controlling authority (USCINCSPACE). The cryptoperiod for CVWs is 1 week.

a. GUV Key. The GUV will be the primary key issued. GUV users will be segmented into groups, each group with its own unique key. The GUV is a key encryption key--a key that encrypts or decrypts another key. Specifically, the GUV encrypts or decrypts the daily cryptovariable, which is the traffic encryption key used in the SA and A-S processes. Use of the GUV allows remote loading of user equipment with a daily cryptovariable by the satellite down link.

b. CVW Key. The CVW will be issued to military users that have a low-security risk and whose mission depends upon rapid reaction (required time to first fix from turn on must be 5 minutes or less) or non-detection. Access to the CVW will be authorized by USCINCSPACE upon recommendation by Service validating authorities and allied Ministers of Defense

(MODs). The CVW is a key production key. It is a key used to produce other keys. Specifically, the CVW is used to automatically generate daily cryptovariables within the user equipment. By using the CVW, user equipment can process SA and A-S sooner because it does not have to obtain the daily cryptovariable from the satellite down link.

c. Crypto Management. The SA and A-S crypto features and associated crypto keys will be managed so that access to PPS may be denied to selected user groups if:

(1) US foreign policy dictates.

(2) Readiness of US forces changes.

(3) Friends become adversaries.

(4) The United States cannot afford the risk of compromise in providing keys to certain users.

(5) It becomes necessary to recover from an actual or suspected security compromise.

13. Procedures for Approving and Validating GPS-PPS Key Requests. Standard COMSEC procedures apply when requesting, shipping, handling, and destroying GPS keys. However, because the system has worldwide applications, military and civil users, and the number of users exceed those of other cryptonets by several orders of magnitude, some unique or tailored procedures have been developed. Detailed instructions regarding keying material management are available in USSPACECOM Reg 56-1, "GPS PPS Keying Material Management."

a. Controlling Authority. USCINCSPACE is the controlling authority for the GPS cryptonet. USCINCSPACE responsibilities include, but are not limited to: reviewing key requests for compliance with DOD policy regarding GUV and CVW assignments and type of keys authorized, notifying users of changes in crypto key status, and maintaining a consolidated list of GPS crypto accounts.

b. Validating Authorities (US Government). The component space commands are "validating authorities" for US military users. Validating authorities will develop procedures to determine the number and type of keys required by supported users. They will validate requests for keys and will report requirements to USCINCSPACE. The GPS controlling authority will notify validating authorities if a request for keys appears to violate DOD policy. Unresolved conflicts between military validating authorities and the GPS controlling authority will be resolved by the Joint Staff. Unresolved conflicts between validating authorities outside the DOD and the GPS controlling authority will be resolved by the DUSD(Space). The Joint Staff is the validating authority for allied and friendly military users. The DUSD(Space) is the validating authority for US and foreign federal civil government users. Figures D-1 and D-2 outline the key request and approval process. Note that validating authorities are unique to the GPS

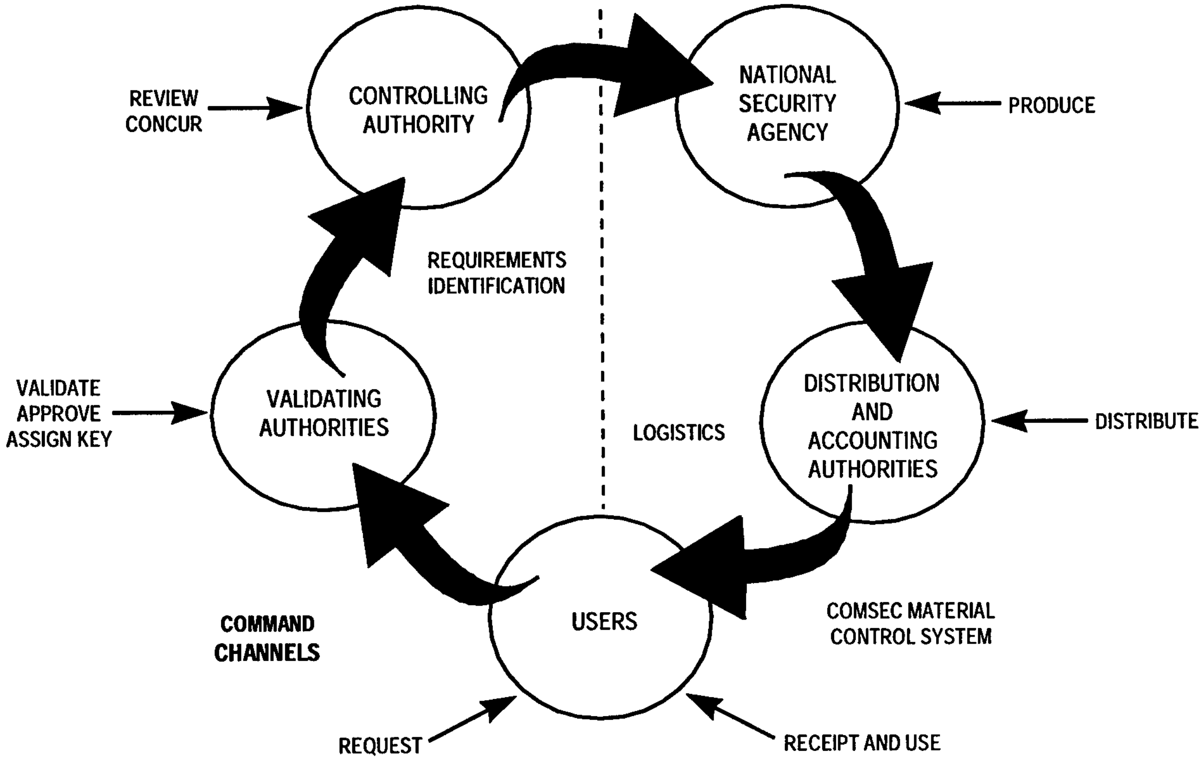


FIGURE D-1. GPS KEYING MATERIAL
REQUEST, APPROVAL, AND DISTRIBUTION PROCESS
FOR DOD USERS

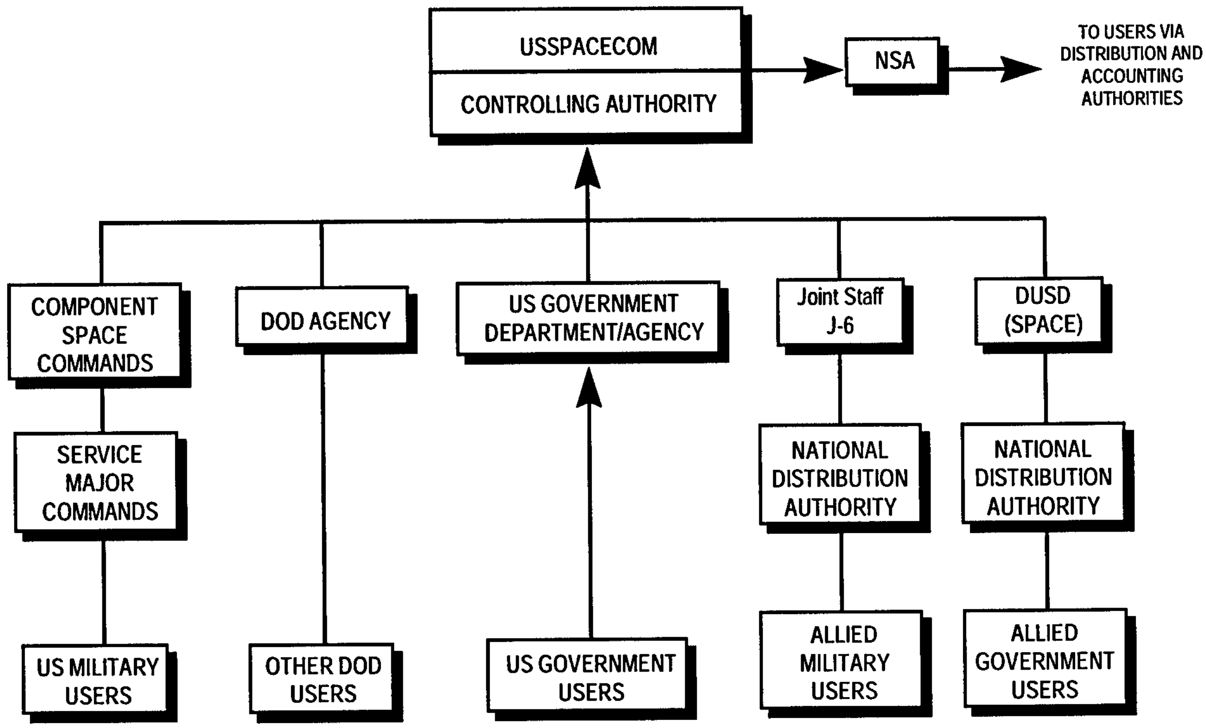


FIGURE D-2. GPS KEYING MATERIAL
APPROVAL HIERARCHY

program and perform functions done by controlling authorities in other keying programs.

c. Allied Civil Government Users. All allied government requests for GPS PPS and associated crypto, even from allied Civil Government bureaus and agencies, must be submitted by the allied government's MOD through the appropriate unified commander to DUSD(Space). Allied government use of GPS PPS must be approved by DUSD(Space) on a case-by-case basis. The DUSD(Space) will consult with appropriate advisors, to include representatives from other US Government departments, to determine if the intended use of GPS PPS is in the US national interest and if the requirement could be reasonably satisfied without PPS. If the allied government request is approved, DUSD(Space) will notify NSA, USCINCSPACE, the unified commander, and the requesting MOD.

14. Satellite Constellation Management. SA/A-S capability testing will be conducted as soon as possible after launch of each GPS satellite. Satellites will be placed in the SA/A-S mode as soon as they are declared operational.

15. Differential GPS

a. Background. Many civil and military GPS users require accuracies that exceed the design capabilities of GPS. Surveying, ship harbor navigation, and aircraft precision approach are a few examples. Consequently, numerous worldwide efforts are under way to increase GPS accuracies by transmitting error-correcting signals, generically called DGPS. These DGPS efforts are under the sponsorship of the US Government (i.e., Coast Guard, and FAA), several European countries, and various private companies. The Department of Defense does not object to establishing and operating DGPS transmitters for peaceful purposes provided corrective data are not derived from GPS PPS receivers or processors and differential systems do not interfere with users of the basic GPS.

b. DOD Differential Policy. The Department of Defense will operate insofar as possible using the PPS received directly from the GPS satellite constellation as the primary source of PNT information. Additionally, the Department of Defense is considering methods to improve the direct reception accuracy available from PPS to satisfy high-precision positioning, timing and navigation needs in authorized military platforms without requiring differential corrections. To the extent the Department of Defense uses differential GPS for combat operations, the differential systems must use the PPS, and the differential corrections must be encrypted for transmission and processing. DOD PNT users may use US civil systems for peacetime operations where their use does not jeopardize DOD ability to carry out its military mission. Use of foreign DGPS systems that are not provided by countries with defense arrangements with the Department of Defense are prohibited. The preceding prohibitions do not apply to ships and aircraft in peacetime navigation scenarios as long as the system(s) in use are IMO or ICAO recognized systems, respectively.

(1) The Department of Defense plans to deny access to C/A-code signals, C/A-code-derived DGPS, and other precise PNT systems in local combat theaters or other areas of national security interest.

(2) DOD GPS users may use civilian-provided SPS-based DGPS services when civil agencies have defined navigation accuracy, integrity, availability, and continuity of service requirements that exceed direct reception PPS capabilities, where operation is in the interest of the Department of Defense, and where such use will not result in adverse effects to military missions.

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ENCLOSURE E

GPS USER EQUIPMENT ACQUISITION POLICY

1. Objective. The objectives of the DOD user equipment acquisition policy are to: a. preclude duplication of user equipment development efforts and associated costs by concentrating the development of military unique user equipment at the GPS Joint Program Office (JPO), b. enable the Department of Defense to benefit from the rapid technological advances occurring in the civil GPS market, c. promote the purchase of user equipment from competitive sources that have been technically and security prequalified by the GPS JPO, d. support employment of GPS as the primary radionavigation system for use by all forces, e. preserve the military competitive advantage and force enhancement capabilities derived from direct access to the GPS-PPS, and f. ensure DOD airborne users meet an "Equivalent Level of Service" for operation within the National Airspace System (NAS) and within the International Civil Aviation Organization (ICAO) airspace.

2. Acquisition Policy

a. The GPS JPO is responsible for the development of Host Application Equipment (HAE) designed to satisfy unique military requirements, i.e., Y code direct access, jam resistant antennas. Additionally, the GPS JPO will control the development and production of PPS HAE security devices. The GPS JPO and NSA will jointly produce and update government specifications (or interface control documents) that define the mechanical, electrical, and functional interfaces for advanced PPS HAE security devices. While the GPS JPO has overall management responsibility for this project, NSA is responsible for reviewing and approving the cryptographic techniques that will be integral to these security devices. Further, NSA will lead efforts to ensure that higher levels of microcircuit integration associated with these advanced security devices do not blur the required security boundaries. The GPS JPO and NSA will jointly update existing security documentation to ensure that security guidelines adequately protect the classified GPS data processed by these security devices.

b. The JPO will also ensure GPS user equipment intended for use on DOD aircraft operating in civil airspace meets established standards for accuracy, integrity and safety. Consistent with operational capability, acquisition of airborne user equipment will include a process to identify and mark the equipment with the class codes found in the applicable FAA TSOs, alternative military standards, or other applicable civil standards. JPO will ensure user equipment installations meet the varied performance standards for operations in civil airspace, and when equipping a civil-derivative DOD aircraft, the JPO will ensure the equipment and installation receives FAA certification for operations in civil airspace.

c. As of June 1997, the GPS JPO had security qualified PPS HAE products from 31 US manufacturers. DOD GPS users may acquire user equipment through the GPS JPO or directly from GPS JPO approved vendors. The catalog of JPO approved PPS HAE vendors and the respective hardware and software products is updated and published semiannually in January and July. To obtain a copy of the catalog and to be included on the formal distribution list, submit requests to the GPS JPO Systems Engineering Division (SMC/CZE).

3. Security. All combat and combat support forces, to include unmanned vehicles and missiles, must be equipped with PPS HAE that incorporates both selective availability and antispoofing features since SPS user equipment will be subject to jamming and spoofing in combat theaters. Waiver requests submitted by Service Acquisition Executives for use of SPS equipment in specific platforms or application categories that do not involve combat operations and do not require direct PPS accuracy (test and evaluation, survey, training, etc.) will be considered by the DUSD(Space) and coordinated with the Joint Staff/J-6. DOD aircraft that operate under instrument flight rules in controlled airspace must use equipment which meets the intent of appropriate FAA Technical Standard Orders but use of such equipment will neither force the Department of Defense to compromise the combat employment of PPS HAE systems nor extend requirements for other radionavigation aids to supplement GPS. Also, all development or procurement of PPS HAE equipment, including special applications listed above, must be coordinated with the GPS JPO to ensure that GPS technical security requirements are satisfied.

4. Specialized Equipment Policy. The development, manufacture, installation, and operation of GPS PPS satellite signal simulators (SSS) and pseudolites require special security controls beyond those applied to GPS PPS HAE. Such efforts will be accomplished in accordance with the Guidelines for Navstar Global Positioning System (GPS) Precise Positioning Service (PPS) Satellite Signal Simulators, published by the GPS JPO. Access to GPS PPS signal simulators is limited to the US Department of Defense, authorized foreign government defense organizations and associated contractors for use only in the development and logistic support of GPS PPS equipment. Access to GPS PPS pseudolites is limited to the US Department of Defense and associated US contractors for use only in test range applications and for developing and implementing operational tactics. Operational crypto keys are not authorized for use with GPS PPS signal simulators or pseudolites. Test keys will be used.

5. GPS Cryptography. The United States shall use only US designed, built, and integrated GPS cryptography. US procurement contracts for GPS PPS equipment, such as PPS UE and PPS signal simulators, must be awarded to US companies. Foreign teaming, licensing, and subcontracting are allowed. However, to comply with the above restrictions, participants must clearly demonstrate that the cryptographic functions and associated hardware are designed, built, and integrated by a US company and are separately auditable. The US company must be free from foreign ownership, control, or influence.

ENCLOSURE F

OPERATIONAL PNT SYSTEMS--
DESCRIPTIONS AND CHARACTERISTICS

1. General. This enclosure describes the characteristics of operational PNT systems currently used by the US Army, USN, USAF, USMC, DISA, and NIMA. Two general categories of PNT systems are described: a. PNT systems that use radiated signals from an external PNT source for navigation or relative bearing and distances determination, and b. self-contained PNT systems that do not require reception of externally generated signals and can provide capabilities that may not be available from radionavigation systems in a hostile environment. Major PNT system requirements that have universal use are discussed using the parameters addressed in Enclosure B. Special or limited-use systems are described briefly and information regarding system performance parameters have been included where practicable. Current or deployed systems are discussed in this enclosure. Developing systems are discussed in Enclosure G.

2. PNT System Performance Parameters. Navigation systems described in this plan are defined in terms of system performance parameters that determine their use and limitations. A description of these parameters follows:

a. Accuracy. Accuracy is the degree of conformance between the estimated or measured navigation output parameter of a platform at a given time and its true navigation output parameter. Because accuracy is a statistical measure of performance, a statement of the accuracy of a navigation system must include a statement concerning the probability level of the estimate or measurement. Specifications of PNT system accuracy generally refer to one or more of the following definitions:

(1) Geodetic Accuracy. The accuracy of a position with respect to the known, surveyed geodetic coordinates of points on the Earth.

(2) Repeatable Accuracy/Precision. The level of repeatability which a user can determine position with respect to a position whose coordinates have been measured at a previous time with the same navigation system.

(3) Relative Accuracy. The accuracy with which a user can measure position relative to that of another user of the same navigation system at the same time or to some reference point such as a beacon or buoy. Relative accuracy may also be expressed as a function of the distance between the two users. For example, a GPS-equipped aircraft might use the geodetic solution of another GPS receiver, located near a runway, as the destination or objective during an approach to landing.

(4) Time Transfer Accuracy. The percentage of time over a specified time interval that the difference between a Universal Coordinated Time (commonly referred to as UTC) time estimate from the position solution and UTC as it is managed by the United States Naval Observatory (USNO) is within a specified tolerance.

b. Availability. The availability of a navigation system is the percentage of time that the services of the system are usable. This is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter. Availability is also an indication of the system's ability to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from external sources are available for use. To consider a system available for aviation use in civil controlled airspace, the system must meet both accuracy and integrity requirements.

c. Coverage. The coverage provided by a radionavigation system is that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy. Coverage is influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, and other factors that affect signal availability.

d. Reliability. The reliability of a navigation system is a function of the frequency with which failures occur within the system. It is the probability that a system will perform its function within defined performance limits for a specified period of time under given operating conditions. Formally, reliability is one minus the probability of system failure.

e. Integrity. Integrity is the ability of a radionavigation system to provide timely warnings to enable a user to determine when the system should not be used for navigation to support the mission or phase of operation.

f. Fix Rate. Fix rate is defined as the number of independent position fixes or data points available from the system per unit of time.

g. Fix Dimensions. This characteristic defines whether the navigation system provides a one-dimensional line of position (LOP), or a two- or three-dimensional position fix. The ability of the system to derive the fourth dimension (time) from the navigation signals is also included.

h. System Capacity. System capacity is the number of users a system can simultaneously accommodate.

i. Ambiguity. Ambiguity exists when the navigation system identifies two or more possible positions of the vehicle, with the same set of measurements, with no indication of which is the most nearly correct position. The potential for system ambiguities should be identified along with a provision for users to identify and resolve them.

j. Continuity of Service. Continuity of Service is a civil aviation term which is defined as the probability that the navigation accuracy and integrity requirements will be supported throughout a flight operation or flight hour given that they are supported at the beginning of the flight operation or flight hour and that the flight operation is initiated and predicated on the operation of the service.

3. Radionavigation Systems

a. Global Positioning System

(1) Description. The GPS is a space-based positioning, velocity, and time distribution radionavigation system. GPS is divided into three segments--the space segment, control segment, and user segment. The GPS satellite constellation consists of 24 satellites. Each satellite generates a navigation message based upon data periodically uploaded from the control segment and adds the message to a 1.023 MHz Pseudo-Random Noise (PRN) C/A and a 10.23 MHz precise Y code sequence. The satellite modulates the resulting code sequences onto a 1575.42 MHz L-band carrier to create a spread spectrum ranging signal. Also, each satellite transmits the navigation message and the Y code at 1227.6 MHz. The satellite design requires minimal interaction with the ground and allows all but a few maintenance activities to be conducted without interruption to the ranging signal broadcast. The GPS Control Segment is composed of three major components: a Master Control Station (MCS), ground antennas, and monitor stations. The MCS is located at Falcon Air Force Base, Colorado, and is the central control node for the GPS satellite constellation. Operations are maintained 24 hours a day, 7 days a week throughout each year. The MCS is responsible for all aspects of constellation command and control, to include:

(a) Routine satellite bus and payload status monitoring.

(b) Satellite maintenance and anomaly resolution.

(c) Monitoring and management of GPS performance in support of all performance standards.

(d) Navigation data upload operations as required to sustain performance in accordance with accuracy performance standards.

(e) Prompt detection and response to service failures.

The control segments' three ground antennas provide a near-real-time telemetry, tracking, and commanding interface between the GPS satellites and the MCS. The five monitor stations provide near-real-time satellite ranging measurement data to the MCS and support near-continuous monitoring of constellation performance (approximately 92 percent global coverage with all monitor stations operational).

(2) Accuracy. The military navigation user equipment will provide a geodetic accuracy of 16 m or better SEP (17.8 m, 2 drms, horizontally and 27.7 m, 2 sigma, vertically). Velocity accuracy will be 0.2 m/sec (2 sigma) in each of the three dimensions. Accurate velocity is a critical input to various weapon delivery computers. Timing accuracy will be 100 nanoseconds or better from UTC. Precise time will be valuable to users who must time-synchronize other systems (e.g., JTIDS). Observed accuracy has been better than specification (8-10m).

(3) Coverage. The probability of 4 or more satellites in view over any 24-hour interval, averaged over the globe, with a PDOP of 6 or less, and a 5-degree mask angle with no obscura, is 99.90 percent.

b. Radiobeacons

(1) Description. Radiobeacons are nondirectional transmitting stations that operate in the LF and MF bands. A radio direction finder is used to measure the relative bearing to the transmitter with respect to the heading of an aircraft or vessel. Aeronautical NDBs operate in the 190 to 415 kHz and 510 to 535 kHz bands. Marine radiobeacons operate in the 285 to 325 kHz band. The transmissions include a CCW or MCW signal to identify the station. The CCW signal is generated by modulating a single carrier with either a 400 Hz or 1,020 Hz tone for Morse Code identification. The MCW signal is generated by spacing two carriers either 400 Hz or 1,020 Hz apart and keying the upper carrier to give Morse code identification. Some of the longer range marine radiobeacons operate on the same frequency and are time sequenced to prevent mutual interference. The target date to complete phaseout of traditional marine radiobeacons as described herein is 2000.

(2) Accuracy. Accuracy of the bearing information is a function of geometry of the LOPs, compass heading, measurement accuracy, distance from the transmitter, stability of the signal, nature of the terrain between beacon and craft, and noise. Bearing accuracy is about:

±3 to ±10 degrees	Aeronautical
±3 degrees	Marine

(3) Coverage. High-power aeronautical LF beacons provide reliable ground wave capability in excess of 560 km during favorable weather conditions. Marine beacons normally cover an area out to 50 nm or the 100 fathom curve.

c. VHF Omnidirectional Range

(1) Description. VOR is a ground-based radionavigation system used for en route, terminal and non-precision approach air navigation. In most areas of the world, VOR is used as the primary navigation aid for transiting nationally designated airways. VOR stations operate in the VHF frequency band of 108 to 118 MHz. At these frequencies, VOR is a line-of-sight system and the distances at which the signals can be received is a function of altitude and of transmitter power. Two signals are transmitted, one fixed and one rotating. The aircraft receiver compares the phase of the signals and produces a readout indicating the magnetic bearing to the station. There are approximately 14,000 military aircraft equipped with VOR receivers. The target date to begin phaseout of VOR is 2005.

(2) Accuracy. Predictable user accuracy (using rss techniques) is ±4.5 degrees, relative accuracy is ±4.3 degrees, and repeatable accuracy is ±2.3 degrees.

(3) Coverage. VOR has line-of-sight capabilities that limit ground coverage to 56 km or less. At altitudes above 1,525 m, the range is approximately 190 km; above 6,100 m, the range will approach 375 km. En route stations radiate approximately 200 watts. Terminal VOR stations are rated at approximately 50 watts and are designed for use within terminal areas.

d. Distance Measuring Equipment

(1) Description. DME stations are normally collocated with VOR stations to provide the user with distance from the station. The DME interrogator in the aircraft generates a pulsed signal (interrogation) that, with the correct frequency and pulse spacings, is accepted by a ground transponder. In turn, the transponder generates pulsed signals (replies) that are sent back and accepted by the interrogator's tracking circuitry. Distance is calculated by measuring the total round trip time of the interrogation and the reply. DME operates in the 960 to 1,213 MHz frequency band (except 1,030 and 1,090 MHz) with a separation of 1 MHz. The target date for DOD phaseout of the requirement for DME is 2000.

(2) Accuracy. Ground station errors are less than 0.1 nm. The overall system error (airborne and ground rss) is no greater than 0.5 nm or 3 percent of the distance to the station, whichever is greater. A precision DME working with MMLS will provide 30 m (2 drms) accuracy on the last 13 km of an approach.

(3) Coverage. DME is a line-of-sight system that limits ground coverage to 56 km or less. At altitudes above 1,525 m, the range will approach 190 km. Those stations radiate 1,000 watts. Terminal DMEs radiate 100 watts and are only intended for use in terminal areas.

e. Tactical Air Navigation

(1) Description. TACAN is an airborne, ground- or ship-based radionavigation system that combines the bearing capability of VOR and the distance-measuring function of DME. It uses 252 channels, in the 960-1215 MHz band, the same frequency band as DME. TACAN transmitters are primarily used by military users and are frequently collocated with VOR stations, particularly along federal airways. When TACAN is collocated with a VOR, the collective installation is called a VORTAC. The signal consists of rotating coarse azimuth (15 Hz) and fine azimuth (135 Hz) elements. Reference signals in the form of pulse trains are added to the radiated signal to provide electrical phase. The 135 Hz sine wave signal provides additional accuracy thereby reducing bearing error. Bearing is obtained by comparing the 15 and 135 Hz sine waves with the reference groups. The target date to begin phaseout of land-based TACAN is 2005.

(2) Accuracy. The ground station errors are less than ±1.0 degree (±65 m at 3.75 km) in azimuth for the 135 Hz element and ±4.5 degrees (±294 m at 3.75 km) for the 15 Hz element. Distance errors are the same as DME.

(3) Coverage. TACAN has a line-of-sight limitation that restricts ground coverage to 56 km or less. At altitudes of 1,525 m, the range will approach 190 km; above 5,500 m, the range approaches 245 km. The station output power is 5 kW.

f. Instrument Landing System

(1) Description. ILS is a precision approach and landing system consisting of a localizer, a glideslope, and one to three VHF marker beacons. ILS provides vertical and horizontal guidance information during the approach to an airport runway. The localizer facility and antenna are typically located about 305 m beyond the stop end of the runway and transmit a VHF (108-112 MHz) signal. The glideslope facility is located approximately 305 m from the approach end of the runway and transmits a UHF (328.6-335.4 MHz) signal. Marker beacons are located along the approach extension of the runway centerline. Marker beacons emit 75 MHz signals and indicate to the pilot decision-height points or distance-to-the-runway threshold. The Department of Defense will continue use of ILS until a suitable precision approach replacement is developed followed by an appropriate transition period.

(2) Accuracy. For typical operations at a 3,050-m runway, the course alignment (localizer) at threshold is maintained within ±7.6 m. Course bends during the final segment of the approach do not exceed ±0.06 degree. Glideslope course alignment is maintained within ±2.1 m at 30-m elevation and course bends during the final segment of the approach do not exceed ±0.07 degree.

(3) Coverage:

Localizer	+/-35 degrees (10nm) and +/-10 degrees (18nm) from runway centerline.
Glideslope	Nominally 3 degrees from the horizontal. Transmits a signal 1.4 degrees (1,500 ft) wide at 10 miles from the runway threshold.
Marker Beacons	±40 degrees (approximately) on minor axis (along approach path). ±85 degrees (approximately) on major axis.

g. Precision Approach Landing System (PALS) (AN/SPN-42 or 46)

(1) Description. PALS is a carrier-based landing system that operates in the microwave frequency band (Ka/X Band) and in three modes. Mode 1 is automatic; the system senses deviation from the optimal heading and glide slope and automatically controls the aircraft to touchdown. Mode 2 is pilot controlled; the system transmits deviations to a cockpit instrument. Mode 3 is similar to GCA (see page F-10); in this mode a shipboard operator transmits instructions to the pilot. Also, there is a Mode 1A operation in which the aircraft is controlled automatically as in Mode 1 until it is one-half mile from the carrier. At that point, automatic control is decoupled and the pilot regains control of the aircraft.

(2) Accuracy. Azimuth and elevation, ±0.044 degree.

(3) Coverage. The system can be used up to 15 km from the carrier, within ±55 degrees in azimuth, and -15 to +30 degrees in elevation relative to the landing area.

h. Carrier Systems for Controlled Approach of Naval Aircraft

(1) Description. C-SCAN is an aircraft carrier landing system, similar to ILS, that operates in the microwave frequency band (Ku-Band). Originally designed as an independent monitor for the PALS, C-SCAN can also be used as a primary landing aid. C-SCAN provides azimuth and elevation guidance through use of a cross pointer display.

(2) Accuracy. Relative accuracy is ±0.1 degree in elevation, ±0.2 degree azimuth.

(3) Coverage. Approximately 19 km from the carrier: (+20 degrees in azimuth, 0 to 10 degrees in elevation).

i. Marine Remote Area Approach and Landing System (MRAALS)

(1) Description. The MRAALS is a two-person transportable, all weather instrument landing system that transmits azimuth and elevation angle data and range data to suitably equipped aircraft. The airborne system translates the data and provides glideslope, localizer, and range and rate information to the pilot indicators. The AN/TPN-30 transits azimuth and elevation data in the Ku-band frequency range (15.412 to 15.688 GHz) and DME data in the L-band frequency range (962 to 1213 MHz). It can be set up in one of two configurations; collocated or split site. The collocated site, for landing zones, uses one AN/TPN-30 to provide azimuth, elevation, and range data. The split site, for airfields and airports, uses two AN/TPN-30s--one at the end of the runway that provides azimuth data, and one parallel to the runway that provides elevation and range data. In the collocated configuration, the AN/TPN-30 can be remotely controlled (up to 1,000 ft) using field wire by the C-10195 and TPN-30 Remote Control or by the C-10194 and TPN-30 Control Indicator, which also provides status information. In the split site configuration, the C-10194 and TPN-30 Control Indicator is used for remote control and for providing status of the two AN/TPN- 30s, which are synchronized by field wire.

(2) Accuracy. At 1 km from the station, the azimuth accuracy is ±1.74 m, elevation accuracy is ±0.87 m. Range accuracy degrades as a function of distance and is ±70 m at 1 km from the centerline.

(3) Coverage. ±20 degrees in azimuth, 0 to 20 degrees in elevation, 18.5 km from the station.

j. Marine Air Traffic Control and Landing System (MATCLS)

(1) Description. The MATCLS was developed to satisfy the requirement for a precision traffic control and landing system for Navy and Marine aircraft at expeditionary airfields. MATCALS duplicates the functions of the carrier air traffic control center and provides operating space for air traffic and landing controllers plus supporting equipment. Initial MATCALS equipment deliveries consist of the AN/TPN-22 PAR, AN/TSQ-107 Air Surveillance Radar with IFF, and the AN/TSQ-131 Communications Control Subsystem. The AN/TSQ-107 will be replaced by the AN/TPS-73 radar. MATCALS provides PALS mode 1, 2, and 3 landing capability and uses the same airborne equipment as PALS.

(2) Accuracy. Azimuth, $\pm$3 m at 1 km from aircraft touchdown point. Elevation, $\pm$2 m at 1 km.

(3) Coverage. $\pm$23 degrees from runway heading. Elevation, -1 to +7 degrees. Distance advisories are available on all headings.

k. Mobile Microwave Landing System (MMLS)

(1) Description. The USAF has developed and is deploying 37 MMLS systems for contingency operations. The MMLS will be used by USF C-130s equipped with modified commercial MLS avionics and USAF C-17s equipped with Precision Landing System Receivers (PLSR). The PLSR is a USAF Multi-Mode Receiver (MMR) with ILS, MLS, and DGPS is also in development.

(2) Accuracy. MLS azimuth and elevation accuracy for the split-site configuration on a 12,000 ft runway is $\pm$30 ft and $\pm$6 ft, respectively, at the Category II decision height of 100 ft. Azimuth and elevation accuracy for the collocated configuration on any length runway is $\pm$65 ft and $\pm$15 ft, respectively, at the Category I decision height of 200 ft. Accuracies include allowances for the avionics. The DME transponder accuracy is $\pm$33 ft.

(3) Coverage. Data over an area bounded by $\pm$40 degrees from runway centerline, -0.9 to +15 degrees elevation and up to 15 nm range from the runway threshold.

l. Direction Finding

(1) Description. Direction finders provide the capability to determine a relative bearing on any UHF radio transmission and are used primarily in air traffic control and as a backup navigation system, particularly between moving platforms.

(2) Accuracy. Relative accuracy $\pm$3 to 5 degrees.

(3) Coverage. Line-of-sight from the transmitter.

m. Ground Controlled Approach (GCA) and Precision Approach Radar (PAR)

(1) Description. GCA has been a precision landing aid for military aircraft since World War II. Ground-based radar provides the operator with aircraft position relative to a fixed approach path. The operator announces aircraft location relative to the glideslope until the pilot has visual contact with the runway or until a minimum altitude is reached. Special aircraft equipment is not required. All voice instructions are passed by standard VHF and UHF radios. GCA and PAR are the NATO standard precision landing systems and are tactically deployable. GCA will remain operational until a suitable replacement is deployed.

(2) Accuracy. Relative accuracy is ±1.3 degrees in azimuth, ±1.1 degrees in elevation, and ±60 m in range.

(3) Coverage. Approximately 18.5 km from the runway threshold.

n. Polarfix

(1) Description. Polarfix is commercial, GaAs-Laser (904 nm), range-azimuth, auto tracking, positioning system. Polarfix is used by the Navy for precise positioning on degaussing ranges, and by the US Army Corps of Engineers for hydrographic surveys.

(2) Accuracy. ±0.5 m ±0.01 percent of measured distance.

(3) Coverage. 5 km.

4. Radar Beacons

a. Aircraft

(1) Radar beacons are portable transponders used for targeting aerial bombardment. The beacon transponder is interrogated by an aircraft, and a transmission from the beacon is sent to the aircraft in response to the interrogation. The aircraft radar is then tuned so that only the coded beacon response is displayed on the radar scope. Using an offset bombing mode, the aircraft's radar crosshairs are placed on the beacon while the aircraft attacks a target that is offset at the prescribed range and bearing from the beacon.

(2) Radar beacons are used when poor terrain features provide inadequate radar returns for precise radar bombing; on targets that must be attacked within specified times during darkness or bad weather; when there is a lack of time for detailed mission planning and target study; and to facilitate the assignment of targets after an aircraft is airborne. In a low-threat environment, the maximum offset range is within a 15-nm radius of the target and the minimum aircraft altitude is 1,000 feet above ground level. In a high-threat environment, the maximum offset range is within a 5-nm radius of the target and the maximum aircraft altitude is 1,000 feet above the ground. Coverage degradation occurs from heavy foliage or other methods used to conceal the beacon's presence.

b. Ship. Ship radar beacons are short-range radio devices used to provide radar reference points in areas where it is important to identify a special location or to mark hazards to navigation.

5. Special Purpose Systems (Self-Initiated)

a. Doppler

(1) Description. Doppler navigation is performed using a Doppler velocity sensor, a heading reference, and a navigation computer. Doppler navigation is dead reckoning in that it tracks changes in position from a known starting point. The Doppler velocity sensor determines aircraft velocity and drift angle by measuring the Doppler frequency shift of reflected energy from narrow radar beams transmitted at obligue angles from the aircraft toward the ground.

(2) Accuracy. 0.1 - 0.3 percent. When a typical attitude and heading reference system is used with an accuracy range of 0.5 to 1.5 degrees, the Doppler navigation system error is almost completely dominated by heading errors and will range from 0.9 percent to 2.6 percent of distance traveled.

(3) Coverage. Global.

(4) Fix Rate. Continuous.

(5) Fix Dimension. 2-D.

b. Terrain Contour Matching (TERCOM)

(1) Description. TERCOM uses radar and barometric altimetry to determine a 3-D position by comparing detected terrain profiles with prestored profiles of the terrain being traversed. Position fixes may be used to update INS or Doppler systems. NIMA is producing TERCOM data for use by cruise missiles and there are development efforts to use the system in strategic bombers and remotely piloted vehicles. A similar system is TERPROM that uses a digital map, together with an aircraft inertial or Doppler system, to predict altitude, which is compared to altitude measured by the aircraft's radar altimeter, to correct navigation system readouts. TERPROM also provides ground proximity warnings and automatic terrain following at high speed and low altitude without use of forward-looking radar.

(2) Coverage. Specifically digitized land areas.

(3) Fix Rate. One per digitized update area.

(4) Fix Dimension. 3-D.

c. Bottom Contour Navigation

(1) Description. An echo sounder is used in bottom contour navigation to determine a submarine position by comparing detected terrain

features with bottom contour charts of the sea bottom being traversed. Echo sounders use sonar to detect features of the ocean bottom. Bottom contour information can be used to update an INS or as a direct input to a weapon-launching system.

(2) Accuracy. Radial rms accuracy of bathymetric position- fixing is approximately ±200 m where accurate charts, based on surveys with the requisite accuracy, are available.

(3) Coverage. Coverage is limited to areas where charts that depict bathymetric contours are available.

(4) Fix Dimension. 2-D.

d. Digital Scene Matching Area Correlation (DSMAC)

(1) Description. DSMAC is a target area missile guidance system. Unlike TERCOM, which is a contour matching system, DSMAC utilizes actual photographs of the target area that are digitized and stored in a computer on board the missile. Missile guidance to the general target area is provided by another system such as TERCOM. Once in the vicinity of the target, DSMAC will match the digitized photograph with the surrounding terrain and correct missile guidance to the target. DSMAC is generally used with conventional weapons that require more accuracy than can be provided by TERCOM alone.

(2) Coverage. Target area only.

e. Geomagnetic Navigation. Geomagnetic Navigation is a mode of geophysical navigation whereby a platform instrumented with magnetometers compares measurements of the local magnetic field with prestored maps of the earth's unique magnetic field signature in that area to obtain positioning information. These fixes can be used to update a dead reckoning system or can provide a continual series of fixes. The system neither transmits nor receives man-made signals and provides passive, self-contained navigation for indefinite periods with bounded errors. Feasibility demonstrations have shown positioning accuracies comparable to noncovert techniques. Geomagnetic Navigation is most suitable for surface and subsurface marine platforms.

6. Self-Contained Systems

a. Inertial Navigation Systems

(1) Description. Inertial navigation provides accurate and reliable user platform attitude, position, and velocity information and is capable of worldwide operation over a wide range of velocities, attitudes, and accelerations, regardless of weather or jamming attempts. An INS is a self-contained system that can operate autonomously (e.g., without aids external to the user platform). Before each use, an inertial navigation system must be initialized using known geodetic position and velocity. From a set position, the inertial system provides continuous estimates of position, velocity, and attitude. For all the precision and accuracy of inertial systems, the output is an estimated position and

not a fix. The best inertials still must be updated periodically. The key components of an INS are an inertial measurement unit (IMU), a navigation computer, and a control and display unit. The inertial measurement unit can consist of either a gyro-stabilized (e.g., gimbaled) or strapdown platform on which inertial instruments accelerometers and gyroscopes are mounted. In the strapdown installation, the mounting is on a nonstabilized structure attached to the frame of the vehicle. The navigation computer processes the IMU outputs to generate position, velocity, and attitude data, drive navigation displays, and generate appropriate gyro-torquing commands. Also, the navigation computer provides sequencing functions to properly initialize the IMU before use as a navigator. The control and display unit displays INS data to the user and permits the user to control the INS.

(2) Accuracy. The present standard for a medium accuracy INS includes the following characteristics:

	Aircraft	Ship	Submarine
Position	±1.85	±1.85	±1.85
Drift	km/hr	km/30 hrs time rms	km/14 days time rms
Velocity	±0.76 m/sec	±0.21 m/sec	±0.21 m/sec
Attitude	±2.50 arc min rms	±1.75 arc min rms	±2.00 arc min rms
Heading	±9.0 arc min ±0.030/hr	±2.00 arc min X secant lat	±2.00 arc min X secant lat

(3) Coverage. Unlimited.

b. Major INS Programs

(1) USAF Standard Navigator. The USAF has procured a series of standard inertial systems for wide application in Air Force aircraft. After establishing a form, fit, and function specification, which describes the requirements in detail, candidate equipment was tested and qualified at the Central Inertial Guidance Test Facility. Production equipment was then competitively procured from a qualified source. Two procurements of the AN/ASN-141 were made several years apart, which were installed in A-10A, F-16C/D, HH-60A, FB-111, and EH-60 aircraft. A subsequent procurement was made competitively for the CN-1656/ASN (Litton) and CN-1656A/ASN (Honeywell), which were installed in Air Force A-7, C-17, C-130, RF/F-4C/D/E, EF/F-111 series, HH-53, CV-22, and the Army OV-1E aircraft. A variant of this system, employing many common parts but packaged in a different form factor, was used on the F-15. Another form of the standard inertial system, will be installed in MC-130 E/H, AC-130H, and J-Stars aircraft. The Modular Azimuth Positioning System (MAPS), a derivative of these standard inertial systems, is also being developed to meet Army

indirect fire requirements. MAPS is discussed in more detail in Enclosure G.

(2) Commercial INS. The USAF and USN have procured commercial inertial equipment, designed for use by commercial air carriers and built to ARINC 561 characteristics, for many of their cargo, transport, and patrol aircraft. The advantages of procuring such equipment are no development costs, competitive pricing, state-of-the-art accuracy, high reliability, low operating costs, and widely available service. These systems constitute one-quarter to one-third of the Services' inventory of inertial systems. Commercial system use is a form of standardization in that ARINC standard inertial systems are form and fit interchangeable. With good planning, software compatibility can be achieved among the various applications so that there is also functional interchangeability between the various aircraft, thereby providing a very broad logistic base.

(3) Navy Carrier Aircraft Inertial Navigation System Program. The Navy has developed a family of standard CAINS that meet the most stringent performance, alignment, and environmental requirements of carrier-based aircraft. The first member of this family, the AS/ASN-92 (CAINS I), was installed in the F-14A/B, E-2C, S-3A/B, ES-3A, A-6E, RF-4B, and TC-4C aircraft. The second generation system, the AN/ASN-130A (CAINS 1A), was installed in the F/A-18A/B, AV-8B, and EA-6B aircraft. The third generation, the AN/ASN-139 (CAINS II), which incorporates ring laser gyro (RLG) technology, has been installed in the F/A 18C/D and the F-14D. The fourth generation incorporates both RLG and embedded GPS. This system is expected to be installed in the F/A-18A/B, some F/A-18C/Ds, the F-14A/B, the F/A-18 E/F, the EA-6B, and the AH-1W. The AV-8B, C-2, E-2C and the S—3B plan to replace their existing systems with the AN/ASN-139 or the embedded GPS.

(4) Aircraft Carrier Navigation Systems. The Navy is upgrading the inertial systems in all of its aircraft carriers. The new system consists of 2 AN/WSN-1(V)2 inertial systems, 2 AN/UYK-44 standard digital computers, and 2 CV-2953A(P) signal data converters tied into the MK70 MOD 6 switchboard, which provides the interface between the CVNS and other shipboard equipment. The CVNS supports aircraft inertial alignment and will provide improved reliability and maintainability for that function.

(5) Electrically Suspended Gyro Navigation. ESGN, AN/WSN-3, provides precise, self-contained, worldwide inertial navigation for SSN. The reset interval is 14 days. The USN has developed and certified software for ESGN operation with the SSN navigation subsystems.

(6) AN/WSN-5 Inertial Navigation System. The AN/WSN-5 is currently in production and is being installed on new construction Aegis Cruisers (CGN-42 class), Destroyers (DDG-47 class), and LHD. In addition, the AN/WSN-5 is being backfitted on the following classes of ships: DD-963, CG-16, CG-26, DDG-37, and CGN. The AN/WSN-5 is used to provide reference information for weapons launching and for navigation.

c. Attitude and Heading Reference System

(1) Description. AHRS are self-contained reference systems that use gyroscopes, sometimes combined with accelerometers, to establish reference data against which changes in aircraft's heading and attitudes are sensed with respect to a reference coordination system. AHRS provide autonomous, covert, unjammable pitch, roll, and heading information to weapons systems and delivery platforms. Some versions also have magnetic variation data to compute true heading and lower quality accelerometers to provide leveling and velocity information. AHRS generally differ from inertial navigation systems (INS) in that they do not provide the quality of acceleration, velocity, true heading, and position information associated with an INS. AHRS systems are used in helicopters, trainers, and as secondary reference systems for fighter/attack aircraft, certain ships, missiles, tanks, artillery, etc.

(2) Accuracy. Predictable accuracy typically is 200 arc seconds, commercial units, 1 degree.

d. Altimeters, Depth Finders, and Detector Systems. Pressure altimeters are used in all aircraft to determine height either above the earth's surface or above mean sea level. For very low- and very high-altitude operations, radar altimeters are used. Depth finders are used by ships and submarines to compute distance from the keel to the sea bed. Depth detectors measure water pressure to determine a submarine's depth below the surface of the water.

e. Celestial Navigation. Celestial navigation, as traditionally practiced, provides an average error in position of 2 nm. Increased flexibility, more accurate calculations, and decreased time to solution (fix) can be achieved by performing calculations electronically. Accuracies corresponding to 3 to 30 meters on the earth's surface are attained by automated celestial systems, depending on the degree of automation. Automated star trackers on spacecraft, missile guidance systems, and aircraft provide high accuracy, real-time calibration of position and orientation with respect to the absolute inertial reference frame provided by stellar sources. Typically, a star tracker augments an inertial (or other) guidance system. The System To Estimate Latitude and Longitude Astronomically (STELLA) is a computer application that automates all of the calculations of celestial navigation, including derivation of a fix (2-D). It is equally useful for determination of gyro/compass error, and supports the necessary planning activities for both functions with numerical and graphic displays. STELLA eliminates the need for printed tables, log and manual calculations, and can be installed on fixed, portable or lap-top computers for use when needed. STELLA has built-in capability for higher accuracy if used in conjunction with stabilized or compensated sensors vice hand-held instruments.

7. Identification and Air Traffic Control Systems (IATCS). Precise positioning; reliable navigation; identification of friendly and enemy forces; and survivable, secure communications are some of the essential elements of a commander's C3 systems. Consequently, there are current and developing systems designed to satisfy a commander's requirement to command and control his forces

effectively that have a PNT capability as a by-product of their primary function. Current systems are discussed in this section. Developing systems are discussed in Enclosure G.

a. Air Traffic Control Radar Beacon System (ATCRBS)

(1) Description. The ATCRBS is a radar system designed to provide positive identification of aircraft. ATCRBS airborne transponders are set to respond to any of 4,096 possible identification codes. When interrogated by air traffic control radar, the transponder identifies the aircraft and transmits altitude information. The system operates on two discrete frequencies in the TACAN band. In most military aircraft, the ATCRBS function is incorporated with the Mark-XII IFF system.

(2) Accuracy. Relative accuracy is ±300 m in range, ±1.6 to 5.6 degrees in bearing.

(3) Coverage. Omnidirectional from the interrogator within line-of-sight (less than 250 nm).

b. Air Traffic Control Radar

(1) Description. Air traffic control radars are ground- or ship-based aircraft surveillance systems used to control en route traffic and to provide sequencing and separation in terminal areas.

(2) Relative Accuracy. ±150 m in range, ±1.2 degrees in bearing.

(3) Coverage. Dependent upon altitude.

8. Fire Control Position/Azimuth Equipment

a. Stabilization Reference Package/Position Determining System (SRP/PDS). SRP/PDS is used on the Multiple Launch Rocket System. The SRP provides direction, elevation, and cant (slant) angle to the fire control system. The PDS provides position location data utilizing input from the SRP and two odometers connected to the vehicle tracks. The system must be initialized and updated at survey control points.

b. Position and Azimuth Determining System

(1) Description. PADS is a self-contained INS used to provide field artillery survey data (UTM coordinates, heights, and direction) critical to weapon systems and target acquisition platforms.

(2) Accuracy. 4 m (CEP) horizontal, 2 m (PE) vertical, and 0.4 mil (PE) directional using 5 minute zero velocity updates; or 7 m (CEP) horizontal, 3 m (PE) vertical, and 0.4 mil (PE) directional using 10 minute zero velocity updates.

(3) Coverage. 7 hour or 55 km mission duration.

c. Survey Instrument, Azimuth Gyro, Lightweight (SIAGL)

(1) Description. SIAGL is a man-portable, north seeking gyroscope that is capable of determining true north. SIAGL is used by USA engineers and artillery survey sections to determine directions needed to conduct survey operations in a combat zone.

(2) Accuracy. Predictable accuracy of bearing information is +/-0.150 mil divided by the cosine of the latitude.

(3) Coverage. Worldwide from 0 to 75 degrees latitude.

d. North Seeking Gyro (NSG)

(1) Description. NSG is a vehicular-mounted north seeking gyroscope capable of determining true north. It is used on artillery fire support team vehicles (FIST-V) to provide direction and elevation altitudes for the laser designator.

(2) Relative Accuracy. Azimuth error 8.5 mils (1 Sigma) after 1 hour, vertical angle error 3.5 mils (1 Sigma) after 1 hour.

(3) Coverage. Worldwide from 0 to 75 degrees latitude.

9. Joint Tactical Information Distribution Systems (JTIDS)

a. Description. JTIDS is a command and control system that will provide real-time, secure, low probability of exploitation and intercept, jam-resistant, and line-of-sight digital data and voice communications. Over-the-horizon (OTH) communications are possible when JTIDS-equipped platforms act as relays for others. JTIDS has an inherent relative navigation capability that provides relative position information and navigation in a tactical grid network. A JTIDS terminal can be programmed to emulate, on a time-shared basis, the performance of a TACAN transponder.

b. Accuracy. The relative accuracy of a fix obtained from JTIDS is 75 m, provided there is a minimum of four platforms in suitable geometric position.

c. Coverage. Tactical theater.

ENCLOSURE G

RESEARCH AND DEVELOPMENT

1. Introduction

a. The Services are responsible for developing, testing, evaluating, operating, and maintaining aids to navigation and user equipment for military missions. The Department of Defense is responsible for ensuring that military vehicles operate in accordance with civil navigation rules and procedures. This enclosure describes major R&D activities affecting military systems that have positioning or navigation functions. The driving requirements for these activities are the mission requirements of the commanders of combatant commands (CINCs). The future operational capabilities of PNT systems depend on technologies developed by Service R&D programs. The Services maintain primary responsibilities for their own requirements and systems. However, interdependencies of navigation and weapon systems dictate a joint review of total navigation R&D resources.

b. The information presented in this enclosure is intended to assist in the development of an overview of navigation systems currently in R&D, permit reevaluation of planning that might duplicate similar capabilities, identify those systems where similarities would allow possible reduction in costs, and ensure proper allocation of resources. Detailed descriptions of several major multi-Service systems are included. INS, although not necessarily a multi-Service system, is classed under the major system section because it is used throughout the civil and military communities. Descriptions of other navigation systems that are of interest to more than one Service are included. Single-Service systems are included for general information purposes and to document current navigation R&D efforts within the Department of Defense.

2. Background. Unique Service requirements and different approaches to acquisition have led to a wide range of implemented and planned navigation systems. Rational allocation of resources requires the minimum number of navigation systems to satisfy the maximum number of validated requirements. The Department of Defense uses two major types of PNT systems: radionavigation systems and self-contained or self-initiated (Doppler) systems. Some C2 systems, such as JTIDS and NAVAL LF/VLF communications, have an inherent navigation capability as a by-product of their design. Currently, the Services use several different PNT systems and are conducting research on new systems. Developing PNT systems should present significant opportunities for replacement and phaseout of several older systems. Tradeoffs with other systems will be required to determine which systems can be replaced. The overall effect will be a reduction in numbers of systems currently being developed or in use, with potential savings in costs, weight, and platform space.

3. Objectives. The objectives of DOD PNT R&D programs are as follows:

a. Support the achievement of stated CJCS PNT goals and objectives.

b. Combine improvement of systems with reduction of costs and duplication.

c. Lower development and acquisition costs.

d. Lower operation and support costs.

e. Fewer systems satisfying more requirements.

f. Effective and efficient use of existing and developing systems.

4. New Systems

a. Differential GPS (DGPS)

(1) Description. The Services are investigating the use of DGPS for meeting precision approach requirements as part of the JPALS program. Possible architectures include the FAA's Wide Area and Local Area augmentations to the basic GPS signal. Another candidate is the Coast Guard's maritime DGPS system. P/Y-code systems are preferred over reliance on civil C/A-code signals.

(2) Accuracy. Accuracy for the FAA WAAS is projected to be 7.6 meters (95 percent). Civil flight tests for code-based local area DGPS have shown 3-5 meter (95 percent) vertical accuracy. Accuracy for the LAAS is expected to provide for Category II and III precision approach flight requirements. The Coast Guard's DGPS is providing accuracy that has been demonstrated at better than 2 meters (95 percent).

(3) Other. Other issues such as integrity and availability are under study. The JPALS assessment of alternatives will address these parameters.

b. Position Location Reporting System

(1) Description. Position Location Reporting System (PLRS) is a USA and USMC system of digtal UHF radios that will automatically provide commanders with accurate, near-real-time identification and relative location data on ground forces, helicopters, and selected fixed wing aircraft. The Army will field an enhanced version of PLRS (EPLRS) that will accommodate the additional data handling requirements associated with the forward area air defense system (FAADS). The heart of the PLRS network is the master station, which is housed in a transportable S-280 shelter that can be truck-mounted or airlifted by helicopter. Each master station contains three computers, a display console, and communications equipment. A typical division deployment will consist of 600 to 900 user terminals and up to five net control stations. User units, which come in manpack, vehicle, and airborne configurations, automatically transmit data to the master station that uses triangulation techniques to determine accurately the position of all user units.

(2) Accuracy. Relative accuracy (dependent on velocity) is 25-30 m (horizontal). Vertical error will be 3 percent of platform altitude.

NOTE: The agreement between PLRS-derived coordinates and corresponding map-scaled coordinates will vary as a function of the map's inherent accuracy and the errors in the transformation from WGS 84 to the local mapping datum.

(3) Coverage. Division tactical area plus extended area coverage of 100 nm for aircraft.

(4) Reliability. 97-98 percent.

(5) Fix Rate. Platform dependent (varies from 0.5 to 64 seconds).

(6) Fix Dimension. 3-D.

c. Precision Landing System Receiver (PLSR)

(1) Description. The Air Force Electronic Systems Center is developing the PLSR. The PLSR is a multi-mode landing system receiver that provides frequency compliant ILS, MLS and differential GPS landing modes. The PLSR will operate against the existing ILS ground stations and both the Fixed Base and Mobile MLS. The Electronic Systems Center is also investigating the feasibility of a P/Y-code differential GPS ground station through a Cooperative Research and Development Agreement. The PLSR has been flight tested with a prototype DGPS ground station. These results will be incorporated in the JPALS assessment of alternatives.

d. Air Traffic Control and Landing Systems

(1) HQ USAF Mission Need Statement (MNS) 001-96 Air Traffic Control and Landing Systems. This MNS identifies the ground-based components of the future Communications, Navigation, Surveillance (CNS) system that forms the next-generation air traffic management concept of operations. The MNS states the requirement to move towards a space-based digital network of interconnecting avionics, space-based, and associated ground equipment components that will form the future air traffic management system. It identifies the need to have a common system for both fixed-base as well as theater deployable systems. The MNS identifies the need for the future air traffic controllers work station to receive, process, and display Automatic Dependent Surveillance (ADS) inputs, Mode-S, and satellite-derived data link information. It identifies the need for a single integrated display system for real-time processing of flight plan information, airspace management, multi-level weather, digital mapping, and geodesy information.

(2) Digital Airport Surveillance Radar (DASR). This new- generation digital radar is a jointly procured system between the FAA and Department of Defense, with the USAF designated as the lead acquisition agency. The DASR will replace the ASR-7/8 (GPN-12/20) systems and provide many of the surveillance capabilities necessary to process future air traffic management data. The digital format allows for multi-sensor processing and remote monitoring of position data. Additionally, the mono-pulse beacon system provides more accurate aircraft position fixing plus the capability to upgrade Mode-S signal processing. It also provides 6-level, color weather processing for display on the air traffic

controller's display. DASR will begin replacing the GPN-12/20 systems in the 1998/99 time period. Fielding will continue through 2005.

(a) Coverage. Primary radar coverage is 60 nm radius from antenna to 24,000 feet AGL. Secondary radar coverage is 120 nm radius from antenna to 60,000 feet AGL.

(b) Accuracy. Primary radar will track 1 square meter target with azimuth accuracy of 0.16 degree rms and range accuracy of 0.125 nm at the 0.80 probability of detection (Pd). Secondary radar (i.e., Beacon) Pd is 0.995 with azimuth accuracy of 0.08 nm and range accuracy 190 feet rms.

(c) Reliability. 99 percent.

e. Other Systems

(1) Doppler Log. The purpose of the Doppler Sonar Velocity Log (DSVL) project is to develop a highly accurate DSVL for precise measurement of the velocity of submarines and ships. Improvements will minimize speed-related errors being introduced into fire control and navigation systems. DSVL offers an error rate less than 0.07 m/second (95 percent of the time) when speeds are less than 4 m/second and 1.75 percent of the speed (95 percent of the time) for speeds greater than 4 m/second. MTBF will be greater than 3,500 hours for a 60-day mission, and mean-time-to-repair will be less 30 minutes.

(2) Advanced HF Submarine SONAR. The advanced HF submarine SONAR is a space saving, multifunction, high-frequency, integrated element of the combat system on a smaller, cheaper submarine. The system will provide mine detection and avoidance, under-ice navigation, acoustic communications, active-target tracking, threat-weapon alert and tracking, bottom navigation, and intelligence collection using a broad band of high acoustic frequencies. Development will be conducted in close coordination with the large aperture sensor project to ensure compatibility of acoustic arrays.

(3) Precise Integrated Navigation System (PINS)

(a) The PINS, AN/SSN-2, is a mine countermeasure adaptation of the Integrated Deep Water Navigation System used successfully by USN cable layer and survey ships. PINS will provide flexibility for future growth, redundant capability, integration of sensor information, navigation data, and the plotting capability required for the safe and effective control of mine countermeasure operations.

(b) The AN/SSN-2 system is composed of the following components:

1. Geodetic Navigation--GPS.

2. Relative Navigation--Sonar transponder grid positioning system.

3. Dead Reckoning Navigation--Doppler sonar navigation.

4. Input Sensors--Minehunting sonar, radar, depth sounder, and gyro compass.

5. Plotting and display Systems.

6. Computer--Controlled integration of all inputs including a means of smoothing and averaging inputs.

7. AN/WSN-2.

(c) Using the relative positioning equipment the system is capable of accuracies of $\pm$5 m with GPS.

(d) Most of the hardware components are off-the-shelf. The dedicated mine countermeasures software required to integrate the entire system represents the major effort in this development.

(4) Modular Position and Azimuth System (MAPS) and MAPS-Hybrid (MAPS-H). The MAPS is an inertial navigation and orientation determining system consisting of a dynamic reference unit, a vehicle motion sensor, and a Control/Display Unit. The MAPS followed a "Form, Fit, Function" development effort for use by weapon and target acquisition systems such as the M109 Howitzer, Patriot, Lance, M110 Howitzer, Pershing, FIREFINDER Radar, and others. The MAPS provides position and orientation autonomy, improves response time for fire missions, and permits accurate delivery of steel on target from nonprepared firing positions. The reference unit uses ring laser gyro technology with accelerometers to determine earth rotation rate and vehicle rates giving the user system precise position and orientation. The motion sensor provides distance traveled information and is used to dampen inertial errors. The host display system provides command and control to the reference unit. The MAPS-H is the integration of the GPS hand-held receiver with the MAPS reference unit. GPS will aid the MAPS by providing the initial starting position for the MAPS normal alignment procedure, providing damping of inertial errors, and allows the system to align itself on the move. MAPS-H will allow the host system to operate with either MAPS or GPS independently in the event one system fails.

(5) Improved Instrument Azimuth Gyro Lightweight (SIAGL). This system will replace the old version of SIAGL. It is a nondevelopment item capable of attaining a directional accuracy of 0.2 mil (PE) within 3 minutes after setup. The new SIAGL will be used by field artillery surveyors in conjunction with the Precision Lightweight GPS Receiver (PLGR) to provide accurate directional orientation and position to field artillery firing and target acquisition assets.

(6) Gunlaying Positioning System (GLPS). A tripod-mounted (positioning and orienting device consisting of a gyroscope, GPS, and a short-range, eye-safe laser range-finder. The system will orient and provide position for field artillery howitzer from one centrally located position (orienting station). It will be issued to all self-propelled (non-Paladin) and towed horwitzer batteries. GLPS will orient and establish

position for the first howitzer within 4 minutes after power is applied and within 1 minute for each additional howitzer. Directional accuracy is 0.4 mil (PE), and position accuracy is 10 m (CEP).

(7) Lightweight Laser Designator Rangefinder (LLDR). The Field Artillery LLDR will have the capability to self-locate (through integration with GPS), determine azimuth, vertical angle, and interface with current digital data systems. It will be used by Army light forces fire support teams, combat observation teams, naval gunfire spotters, recon teams, air and naval gunfire liaison company fire control teams, and forward air controllers. It will provide these forces with day/night designation, rangefinding, conventional artillery adjustment, precision-guided munitions capability, and target handover. The system will increase fire support effectiveness, lethality, and survivability while decreasing the quantity of munitions expended.

(8) Integrated Communications, Navigation, and Identification Avionics (ICNIA). ICNIA is a tri-Service program designed to demonstrate that multiple existing and planned near-term communications, navigation, and identification functions in the 2MHz to 5GHz frequency bands can be integrated into one airborne system. ICNIA will be designed primarily for use in tactical aircraft and helicopters and will use advanced technologies, such as very high speed integrated circuits (VHIC) and sophisticated software that will greatly increase reliability and operational availability while reducing weight, size, and cost. A total of 28 hardware module types, using Ada software will be used to configure terminals to meet specific platform communications, navigation, and identification requirements.

(9) Improvements in Precise Time and Time Interval. Over the past several decades, developments in technology for all military electronic systems have led to greater requirements for PTTI. Interoperability of systems throughout all the Services, as well as with NATO, requires accurate common time. Within the next decade, it is anticipated that requirements for PTTI at the 1 part in 10 to the 15th per day (1ps) will exist. In order to prepare for this stringent requirement, the US Naval Observatory (as the provider of the DOD precise reference for time) has begun research and development efforts in advanced clock design and in clock analysis algorithms. In order to better disseminate the time reference, the USNO is developing a Distributed Master Clock System as well as investigating new techniques for time transfer. The Two-Way Time and Frequency Satellite Time Transfer System is currently under tests for very high precision users.

Recently the importance of PTTI technology throughout the Department of Defense was recognized in the, "Special Technology Area Review on Frequency Control Devices," 1 February 1996. It reported that "frequency control device technology is of vital importance to the DOD since the accuracy and stability of frequency sources and clocks are key determinants of the performance of radar; C3I, navigation, surveillance, EW, missile guidance, and IFF systems."

The report continues with some R&D opportunities with potential for meeting future DOD needs. These opportunities include development in high perfection quartz; new piezoelectric materials; resonator theory, modeling and computer-aided design of resonators and oscillators; processing and packaging of high stability resonators; microresonators and thin film resonators; low power, high, accuracy quartz clocks; low noise resonators and oscillators; smart clocks; miniature and high performance optically pumped atomic clocks; and resonator based chemical, biological, and uncooled IR sensors.

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ENCLOSURE H

CONTROL OF PNT SYSTEMS IN TIMES OF TENSION OR WAR

1. General. The JSCP directs the CINCs to address and coordinate control of PNT systems.

2. Security Control of Air Traffic and Navigation Aids (SCATANA)

a. DOD Instruction 5030.36 promulgates the plan for SCATANA on and adjacent to the North American continent. SCATANA is an emergency preparedness plan that prescribes the joint action to be taken by appropriate elements of the Department of Defense, FAA, and FCC in order to effect control of civil and military air traffic and short-range or regional federal and nonfederal air navigation aids (TACAN, VOR/DME, Loran-C, etc.). As of the date of publication of this plan, DOD Instruction 5030.36 is under review and when released may promulgate a SCATANA policy with a broader focus than that reflected in the current instruction.

b. SCATANA authorizes, under dire emergency conditions, the NORAD Region Commander to direct turn-off of short-range air navigation aids that, in his judgment, provide more benefit to enemy forces than US forces.

3. LORAN-C. The decision to turn off LORAN-C transmitters, operated for the Department of Defense, rests with the Chairman of the Joint Chiefs of Staff upon recommendation and coordination with the CINCs. If it is determined that control of a LORAN-C chain is necessary, the CINC making the determination will establish detailed procedures for control of the station or chain and provide those procedures to the Chairman of the Joint Chiefs of Staff, other CINCs, and the USCG Commandant responsible for operating the station or chain.

4. GPS. The decision to change operational modes of the GPS, to degrade accuracy available to civil users, or to terminate GPS PPS to any previously authorized user will be made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. USG provided GPS augmentations will be controlled through agreements between the Department of Defense and the appropriate Federal department or agency.

5. WAAS. The decision to change operational modes of the FAA's WAAS will be made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. As a USG provided GPS augmentation, it will be controlled through agreements between the Department of Defense and the FAA.

6. LAAS. The decision to change operational modes of the FAA's LAAS will be made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. As a USG provided GPS augmentation, it will be controlled through agreements between the Department of Defense and the FAA and/or the cognizant local provider of such services.

7. DGPS. The decision to change operational modes of the USCG's DGPS will be made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. As a USG provided GPS augmentation, it will be controlled through agreements between the Department of Defense and USCG.

8. When commercially provided US differential GPS augmentations are licensed with the FCC, they will be included in SCATANA procedures.

ENCLOSURE I

GEOSPATIAL INFORMATION AND SERVICES

1. Purpose. The purpose of this enclosure is to describe, in general terms, the capability and limitations Geospatial Information and Service (GI&S) products and their relationship with GPS in an effort to maintain continued compatibilities and to explain the use of GPS as a GI&S resource.

2. Background. GI&S products, in some form, have been an integral part of every navigation system and must be linked by a common reference system. The geodetic reference system used by GPS is the DOD World Geodetic System 1984. NIMA, as the proponent agency for all DOD geodetic reference systems and GI&S products, takes an active role in the development and operation of the GPS to ensure continuous compatibility with GI&S products. To ensure this compatibility, there must be early recognition of the ways in which the navigation system will be employed and the GI&S support that will be required. NIMA provided the defining WGS 84 parameters as well as datum shift constants, coordinate transformation formulas, gravity potential coefficients, and a geoid height model.

3. Scope. This enclosure describes GI&S support of the CJCS mission requirements in general terms.

4. Accuracy Objectives. The accuracy requirements approved by the Chairman of the Joint Chiefs of Staff impose rather stringent positional accuracy demands on both potential navigation systems and GI&S products used for mission planning, rehearsal, and execution. DOD users of GI&S products must be aware of the fact that all products do not exhibit the same level of absolute and relative accuracy. Some products such as the Digital Point Positioning Data base (DPPDB) are designed to support the demanding accuracy requirement of Precision Guided Munitions, while topographic maps serve a different purpose. Users must choose the appropriate set of GI&S products which support the mission objectives.

a. Discussion

(1) Absolute accuracy of maps and charts is dependent on the accuracy of the geodetic control network upon which those maps and charts are based. The most commonly used maps, the 1:50,000 scale maps, are generally built to a 50 m (Cat II/B), 90 percent circular probability standard, relative to ground control.

(2) Although maps and charts are primary GI&S navigation support products, other GI&S products such as point positioning data bases, digital aeronautical flight information files, digital terrain elevation, and digital feature data also provide highly accurate geodetic positions. A photogrammetrically derived point positioning data base used with the Analytical Photogrammetric Positioning System can provide precise position and elevation data in denied areas. The implementation of a navigation system with those stated accuracies (for example, to support cruise missiles) constitutes a requirement to expedite the development of point positioning data bases or other nongraphic GI&S support as

well as a requirement for improved geodetic control for that area in which the navigation system is to be used.

b. Summary. The accuracy objectives approved by the Chairman of the Joint Chiefs of Staff influence the GI&S community in two major ways:

(1) The need for more accurate GI&S products to support the various navigation systems.

(2) GPS contributes to the GI&S community by increasing the density of accurate geodetic positions worldwide.

5. Worldwide Positioning

a. The World Geodetic System 1984 (WGS 84) provides a common accessible global reference frame for DOD operations. NIMA GI&S products and other geospatial data generated within the DOD use WGS 84 to the maximum extent possible as the global framework (datum) for these products and all DOD operations. This geocentric reference frame uses the center of mass of the Earth as the origin and closely follows international conventions regarding the scale and orientation of the reference frame axes.

b. For many reasons, global geocentric reference frames such as WGS 84 have been adopted rapidly in disciplines such as geodynamics, geodesy and satellite operations. In contrast, some mapping organizations around the world must deal with the labor-intensive process associated with conversion of existing maps to a modern geocentric reference frame (datum). Many existing maps and nautical charts were created with legacy processes which typically used non-geocentric, regional geodetic datums which differ from WGS 84 in some cases, by several hundred meters.

c. To allow use of these older mapping products generated on regional datum's, transformation parameters have been developed which allow a cartographer or other user to convert geospatial data represented on a regional geodetic datum to WGS 84. Note however, the majority of available geodetic transformations exhibit uncertainties in a range between 3 and 25 meters in each of its translation parameters. This level of accuracy may be adequate for some mapping applications, but a significant amount of care must be exercised before a datum transformation is used in an application which requires a specific level of geospatial accuracy. In some cases, datum transformations may not even be available.

d. A long-term goal shared by many mapping organizations is the universal adoption of a modern geocentric reference frame such as WGS 84. Until this goal is achieved, a need for these utilization transformations will persist and users must be aware of the accuracy limitations associated with the datum transformation process.

6. GI&S Data Acquisition. The implementation of GPS has greatly expanded the GI&S positioning capability by providing a means by which worldwide geodetic control networks can be developed. The increased density of geodetic control allowed by GPS can be used to improve target and fix-point data bases to meet expected weapon system requirements.

7. Products. It is probable that use of graphic products in support of present navigation systems will be largely replaced in future systems by the use of digital GI&S data. As systems are developed, digital (and other) GI&S requirements should be addressed as early in the process as possible to ensure that GI&S support will be available when the system is implemented. Users will continue to require graphics to maintain orientation in case of system failure or to predict a passage between digitally recorded points. The requirements for graphics will continue to be satisfied by conventional graphics, grid-rectified photos and photomosaics, gridded photos, or other forms of visual representation that portray position in terms of the navigation system coordinate readout.

8. Geodetic Control. The GPS is extremely useful as a means of expanding the worldwide geodetic control network. Observations conducted over periods of less than a day provide accurate geodetic control points that can be used to strengthen and improve many local geodetic control nets. GPS uses WGS 84, which strengthens the argument for converting all GI&S products to WGS 84. This action would greatly reduce training and equipment costs, decrease datum errors, and provide significant gains in DOD geopositioning efficiency.

9. Artillery Point Positioning. Target area accuracies available with the GPS will expand the GI&S capability to provide timely, sufficiently accurate positional information necessary to support artillery. Artillery positional requirements exist for firing batteries, countermortar radars, other target location sensors, and forward observers. The current doctrine recommends surveying accuracies as follows:

a. Horizontal, 10-30 m relative to the grid being used.

b. Vertical, 2-10 m.

c. Azimuth, from 1.5 to 0.1 mil. (Azimuth requirements vary, depending on the range of the artillery piece.)

10. Bathymetry. Another application of the GPS as a GI&S resource is in the collection of bathymetric data. A USN objective is to provide a self-contained navigation system for ships and submarines based on bathymetry. Initial surveying of bathymetric features requires the use of an accurate navigation system, preferably one with a continuous fix capability. If continuous fixes are not available, the accuracy of bathymetric data acquired may be greatly degraded. GPS will permit fast, accurate positioning of bathymetric features by survey ships in all ocean areas.

11. Multisensor Aerial Mapping. It is expected that GPS will provide an airborne sensor platform with a horizontal positioning accuracy that meets the error allowed for production of large-scale topographic maps. This accuracy level can currently be met only by using electronic navigation systems that have a 375 nm range. The difficulty of moving and operating the stations that support these navigation systems limits efficiency and potential area coverage. GPS will extend these accuracies worldwide, greatly increasing the DOD aerial mapping capability.

a. The selection of a map or chart series for a given purpose usually depends on the geographic coverage afforded by the scale of the chart. However, when accuracy is a primary consideration in selecting a map or chart for a particular mission, a knowledge of factors affecting the accuracy, which are directly related to the scale of the product, is important. Production errors associated with the major steps of compilation, negative engraving, and printing are evaluated in hundredths or thousandths of an inch. Because production errors are evaluated with respect to the grid of the map, the evaluation represents relative accuracy of a single feature rather than feature-to-feature relative accuracy. The size of the errors are usually similar for all map and chart scales and, normally, these errors accumulate to approximately 0.04 of an inch (1.0mm) CE 90 percent. The resulting map or chart is usually referred to as a Category B product. Errors associated with Category A products amount to half that of Category B products (0.02 inches or 0.5mm) but few US products are built to that standard, and many are built to even less stringent standards. Table I-1 shows the equivalent distance in feet corresponding to 0.04 (1.0mm) of an inch at various scales.

b. Thus, for a given map or chart scale, the values shown in Table I-1 are the expected horizontal accuracies attainable reflecting a Category B product. For example, if an accuracy of 800 feet, CE 90 percent were required, the selection of a supporting map or chart series is limited to charts to 1:250,000 scale or larger (see Table I-1, page I-4).

c. The vertical accuracy of a Category B chart is normally equal to the contour interval, LE 90 percent. Table I-2, page I-5, shows the accuracy in feet for contour intervals typical of various chart scales and categories.

d. Another factor affecting chart accuracy as a function of scale is the symbolization of features. This creates an error in position because of physical characteristics rather than a random occurrence of error with an associated probability level. For example, the width of a line symbolizing a feature may be 0.012 of an inch on a 1:200,000 scale chart. This corresponds to a ground distance of 200 feet. The same width on a 1:1,000,000 scale chart represents 1,000 feet. Consequently, due consideration should be given to these inherent errors, which are characteristic of the chart scale, when selecting an appropriate series for a project or using an individual chart.

TABLE I-1. HORIZONTAL ACCURACY
EQUIVALENT TO 0.04 (1.0MM) OF AN INCH AT CHART SCALE

CHART	SCALE	DISTANCE FEET	METERS
ONC	1:1,000,000	3,334	1,000
TPC/PC	1:500,000	1,666	500
JOG	1:250,000	834	250
ATC	1:200,000	666	200

TABLE I-2. VERTICAL ACCURACY
CORRESPONDING TO A TYPICAL CONTOUR INTERVAL

CHART	SCALE	TYPICAL CONTOUR (FEET)	ACCURACY (FEET)
ONC	1:1,000,000	1,000/500/250	1,000/500/250
TPC/PC	1:500,000	500/250	500/250
JOG	1:250,000	330	330
ATC	1:200,000	Varies	100

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ENCLOSURE J

PRECISE TIME AND TIME INTERVAL

1. Introduction. Timing services, with various degrees of precision, are required by numerous systems and in support of many critical missions. Radio electronic navigation, secure communications, electronic surveillance, improved identification, collision avoidance, formation flight, air traffic control, missile operations, satellite geodesy, and sun-tracking systems are examples of systems and missions that use precise clock time and frequency synchronization. This enclosure discusses PTTI and the importance to military operations.

2. Responsibilities

a. The US Naval Observatory (USNO), Washington, D.C., is the agency responsible for PTTI reference values for all services, agencies, contractors, and related scientific laboratories, coordinating DOD timing capabilities, analysis, evaluation, and monitoring of R&D and operational PTTI systems.

b. The PTTI points of contact are listed in Item 7 of this enclosure.

3. Requirements

a. Most timing requirements are based on a need for synchronization or coordination among cooperating units of a system or between systems. Although synchronization is maintained internally in some systems, units of others must acquire synchronization independently before participating in system activities. For these and for systems that must operate with other precisely timed systems, a common, accessible standard is needed. The standard for military systems is Coordinated Universal Time, UTC as maintained by the USNO Master Clock, UTC(USNO). This UTC(USNO) is the real-time realization of UTC as determined by the Bureau International des Poids et Mesures, Sevres, France. The contribution of UTC(USNO) to the international time scale is approximately 40 percent. The difference between the time scales is less than 20 nanoseconds (ns).

Time accuracy is the degree to which UTC(USNO) is known or maintained by systems requiring interoperability. It is affected both by onboard timekeeping ability and the accuracy with which the onboard clocks can be periodically updated through UTC dissemination services. Therefore, UTC dissemination accuracies generally must exceed the stated onboard time accuracy requirements. It must be stressed that most military electronic systems require a precise and accurate common time - the reference time as established by the USNO. Accuracy requirements vary among systems, but whether the requirement is in terms of minutes or nanoseconds, a means of referring system clocks to the DOD time reference is necessary.

b. Timing accuracy of one to 100 milliseconds is required for wide area computer networks. There are millions of users of network timing. Emerging fast networks require microsecond accuracy. Celestial navigation requires timing accuracy of 0.1 second.

c. One hundred microseconds are required for some geodetic and geophysical programs, missile technology, and satellite observations. Astronomical time of 100 microsecond accuracy can be provided to some users by corrections for propagation delays in broadcast time signals. There are several thousand military and civilian users having this requirement.

d. Twenty nanoseconds (synchronized clock time) are required by the Department of Defense, NASA, National Ocean Survey, and other users for space tracking purposes.

e. LORAN-C master transmitters were directed by Public Law 100-223 to be within 100 nanoseconds of UTC(USNO). Specific time and frequency requirements for other radionavigation systems may be obtained from the USNO.

f. Some areas for clock improvement are rate accuracy or stability, spectral purity, resistance to environmental factors (including temperature, humidity, acceleration, barometric pressure, radiation, and EMP), quick warm-up, cost, size, weight, power consumption, and reliability.

g. Even greater accuracy requirements are expected for advanced space research, radio astronomy, and testing and development of advanced time systems.

h. Improved clocks and longer intervals between synchronization are required in addition to precision requirements.

i. In order to meet these overall timing requirements, improved timing techniques and standardized components are required to implement timing systems aboard the various platforms and ground facilities.

4. Current Operations. The dissemination of Coordinated Universal Time, UTC(USNO), is accomplished by various methods, relying on different systems. No operational systems exist that are solely designed for PTTI dissemination. Figure J-1 highlights some commonly used techniques.

SYSTEM	MODE	ACCURACY NORMAL	ACCURACY BEST
LORAN-C	Passive	200 ns	50 ns
GPS (Keyed Rx or no S/A)	Passive	25 ns	5 ns
GPS (Unkeyed Rx S/A)	Passive	200 ns	20 ns
GPS Common-view (Keyed Rx or no S/A)	Active	15 ns	5 ns
Two-way satellite	Active	<1 ns	

FIGURE J-1. SYSTEMS DISTRIBUTING UTC(USNO)

Methods of receiving PTTI are described below:

a. The USNO provides certification of clocks or times involved in time dissemination, weapons integration, surveillance, countermeasure systems coordination, and satellite control.

b. USN VLF stations, LORAN-C chains operated by the USCG that have special timing capability, the OMEGA system, and GPS provide PTTI with varying degrees of accuracy.

c. All National Institute of Standards and Technology (NIST) time signal transmissions and some selected foreign transmissions are being monitored in order to make precision corrections available to users and to radio distribution services. This monitoring procedure permits the reference of time signals to any of the major time scales in use including Astronomical Time, Coordinated Universal Time, and GPS time.

Radio broadcast of time signals (coded or plain language time information) are available from the NIST stations WWV and WWVH, a system funded by the Department of Commerce. Time signals are synchronized with the USNO master clock to within one microsecond. The accuracy of signals received beyond line of sight from the stations (with nominal correction for the ionospherically and propagated signal path) is on the order of 1 millisecond.

d. USNO has developed operational procedures for high precision time transfer to selected time reference stations by geostationary communications satellites.

e. DSCS stations maintain precise time traceable to the USNO master clock, and the system serves as a trunk line to provide precise time to certain other facilities. Time comparisons made through the system are operationally accurate to 0.1 microsecond and have the capability of providing time accuracy of 10 to 50 nanoseconds.

f. The USNO provides a voice time announcement and time ticks (accurate to the millisecond level if propagation delays are known from a previous measurement) on DSN 762-1401 and commercial (202) 762-1401. The USNO also has an Automated Data Service (1200, 2400, or 9600 baud, no parity, 8 bits, 1 stop) that provides up-to-date PTTI data including corrections to GPS satellite time signals necessary to derive UTC(USNO) (Phone DSN 762-1503, 762-1062, 762-1610). Computers may be timed by calling (202) 762-1594 (1200 baud). See Figures J-2 and J-3.

TELEPHONE VOICE TIME ANNOUNCER	TELEPHONE TIME FOR COMPUTERS	TIME OVER THE INTERNET
(202) 762-1401	(202) 762-1549 1200 Baud, No Parity, 8 Bit Available Software Timeset (360) 387-9788 CallTime (518)477-4934 PCClock 75046.2272@compuserv.com RightTime (214) 402-9660 Accuset 70254.2017@compuserv.com	Via Network Time Protocol tycho.usno.navy.mil/ntp.htm ml

FIGURE J-2. SOURCES OF USNO TIME

DATA VIA MODEM (USNO ADS)	DATA OVER THE INTERNET
(202) 762-1602 (202) 762-1610 (202) 762-1503 1200 - 14400 Baud No Parity 8 Bit	via Telnet: tycho.usno.navy.mil Login: ads via World Wide Web http://tycho.usno.navy.mil via Anonymous FTP: tycho.usno.navy.mil Login: anonymous Password: your e-mail address Automated e-mail Server Send mail to adsmail@tycho.usno.navy.mil with Subject: index

FIGURE J-3. SOURCES OF USNO INFORMATION AND DATA

g. The USNO provides computer network time synchronization service meeting Internet standard RFC-1305 Network Time Protocol (NTP). USNO NTP servers provide UTC(USNO) with millisecond accuracy over wide area networks. Servers are graphically dispersed to minimize network delay and distribute traffic.

5. Other Issues

a. NATO has produced a Military Operational Requirement for the Provision of Precise Time (MMC-SFM-081-93), dated 28 July 1993. This document has three main provisions: (1) the adoption of an agreed source as precision time reference, (2) the dissemination of the time reference, and (3) the acquisition and maintenance of the precise time reference with the appropriate level of accuracy. The reference was approved as UTC, but the other provisions will require the definition of an architecture of how the various systems will interoperate and maintain the accuracies necessary for the different users and systems requirements.

b. A timing plan, based on utilization of all available means of time transfer (synchronization) superimposed upon timed electronic systems, will continue to be necessary for satisfaction of timing requirements after the transition to GPS.

c. GPS has the capability to provide high precision time transfer of ± 15 nanoseconds with a maximum offset from UTC(USNO) of 50 nanoseconds for all DOD and authorized users worldwide. The GPS is the primary source of PTTI, that is UTC, for operational forces. Military users must consider GPS capabilities under varying conditions.

(1) To ensure that GPS is the best real-time realization of UTC, there are restrictions placed upon GPS by ICD-GPS-202. This document,

which gives the general requirements for GPS, states that GPS time must be maintained within one microsecond of UTC(USNO). There is a further requirement that the transmitted correction to UTC must be within 28 ns (1 sigma). GPS time has been within 100 ns of UTC(USNO), and the correction to UTC has been well within 20 ns.

(2) Because the epoch of GPS time differs from UTC, there are an integral number of seconds (denoted as leap seconds) between the two. The leap seconds and the next announced leap second may be found in the navigation message, subframe 4, page 18.

d. The Navy continues to upgrade the Master Clock System at the USNO to achieve an order of magnitude improvement to one part in 10 to the 15th. This time reference system will be used for both current and projected user systems with PTTI requirements that exceed current capabilities; e.g., GPS.

6. Precise Time Stations. A plan for a Distributed Master Clock is being developed in the event that the USNO may become incapacitated. The Distributed Master Clock will consist of Precise Time Stations, having a reference clock traceable to the UTC(USNO). The nucleus of this Distributed Master Clock is the US Naval Observatory Alternate Master Clock (AMC) Station located at Falcon AFB, Colorado (719-567-6740). The UTC(USNO) dissemination functions will be transferred automatically from Washington, D.C. to Colorado as required. The USNO AMC station became operational March 1996.

The Precise Time Stations are listed below and the numbers in parenthesis indicate the recommended order of succession if the USNO is incapacitated.

Precise Time Stations

US Naval Observatory, Washington, D.C.

(1) US Naval Observatory, Alternate Master Clock, Falcon AFB, Colorado
(2) GPS Master Control Station, Falcon AFB, Colorado
(3) National Institute of Standards and Technology (NIST), Boulder, Colorado
Hewlett Packard, Santa Clara, California
USAF PMEL, Elmendorf, Alaska
(4) Aerospace Guidance and Metrology Center, Newark, Ohio
Haystack Observatory, Massachusetts
(5) Applied Physics Laboratory, Maryland
Pacific Missile Test Center, California
(6) USAF Vandenberg PMEL, California
Jet Propulsion Labs, California
White Sands Missile Range, New Mexico
Eastern Test Range, Patrick AFB, Florida
(7) NIST, Hawaii

The timing at the following sites are coordinated with UTC(USNO):

DSCS Terminals

Camp Roberts, California
Landstuhl, Germany
Elmendorf AFB, Alaska
Ft. Detrick, Maryland
Wahiawa, Hawaii
Ft. Meade, Maryland
Ft. Buckner, Japan

International Laboratories

Paris Observatory, Paris, France
Royal Greenwich Observatory (Laser Station), Greenwich, England
National Physical Laboratory, Teddington, England
Van Swinden Laboratory, Delft, The Netherlands
Technische Universitaet Graz, Graz, Austria
Istituto Elettrotecnico Nazionale, Turin, Italy
Physikalisch Technische Bundesanstalt, Braunschweig, Germany
Observatoire Cantonal, Neuchatel, Switzerland
Istituto y Observatorio de Marina, San Fernando, Spain
National Astronomical Observatory, Tokyo, Japan
Communication Research Laboratory, Tokyo, Japan
National Research Council, Ottawa, Canada
Division of National Mapping, Canberra, Australia

7. Precise Time and Time Interval Military Representatives

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Office of the Assistant Secretary of Defense
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The Pentagon, Room 3D174
Washington, D.C. 20301-3040
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DSN: 225-6123
FAX: (703) 693-2395

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The Pentagon, Room 4D268
Washington, D.C. 20330-1000
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FAX: (703) 697-1215

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Office of the Assistant Secretary of the Army
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SARDA/TC
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Washington, D.C. 20310-0103

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DSN: 225-1447
FAX: (703) 695-3600

Staff Assistant
Office of the Assistant Secretary of the Navy
for Research, Development & Acquisition
The Pentagon, Room 4E732
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COM: (703) 695-6315
DSN: 225-6315
FAX: (703) 697-0172

Navy Sponsor
Oceanographer of the Navy
Chief of Naval Operations (N096)
3450 Massachusetts Avenue, NW
Washington, D.C. 20392-5421
COM: (202) 762-1026
DSN: 762-1026
FAX: (202) 762-1025

DOD/DON PTTI Manager
Superintendent
US Naval Observatory
3450 Massachusetts Avenue, NW
Washington, D.C. 20392-5420
COM: (202) 762-1538
DSN: 762-1538
FAX: (202) 762-1461

8. PTTI Coordinators

US Navy

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INTERNET: dnm@orion.usno.navy.mil

US Naval Research Laboratory
Code 8150
4555 Overlook Avenue, SW
Washington, D.C. 20375-5500
COM: (202) 767-2595
DSN: 297-2595
FAX: (202) 767-2845
INTERNET: beard@juno.nrl.navy.mil

Space & Naval Warfare Systems Command (SPAWAR)
Code PMW-175A
Washington, D.C. 20363-5100
COM: (703) 602-7039
DSN: 332-7039
FAX: (703) 602-1535

US Air Force

US Air Force (AGMC/MLEE)
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DSN: 346-8860/7029
FAX: (614) 522-7631

US Army

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DSN: 987-4275
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GLOSSARY

1-D	one dimensional
2-D	two dimensional
3-D	three dimensional
ADS	Automatic Dependent Surveillance
AF/XOO	Air Force/Operations Directorate
AGL	altitude above ground level
AHRS	Attitude Heading Reference System
AMP	Acquisition Master Plan
AOC	Auxiliary Output Chip
APPS	Analytical Photogrammetric Positioning System
ARGO	Automatic Ranging Grid Overlay
ARTY	artillery
A-S	anti-spoof (GPS)
ASD	Assistant Secretary of Defense
ATACMS	Army Tactical Missile System
ATC	air target chart
ATCRBS	Air Traffic Control Radar Beacon System
AWACS	Airborne Warning and Control System
C/A Code	coarse/acquisition code (GPS)
C/A	coarse acquisition code (GPS)
C3	command, control, and communications
C3I	command, control, communications, and intelligence
CAINS	Carrier Aircraft Inertial Navigation System
CCW	continuous carrier wave
CEP	circular error probable
CG	Cruiser
CGN	nuclear powered cruiser
CINC	commander of a combatant command
CINCCHAN	Commander in Chief, Channel (NATO)
CNO	Chief of Naval Operations
CNS	communications, navigation, surveillance
COMINT	communications intelligence
COMSEC	communications security
CONUS	continental United States
CRD	Capstone Requirements Document
crypto	cryptographic
C-SCAN	Carrier System for Controlled Approach of Naval Aircraft
CVNS	carrier navigation systems
CVW	cryptovariable weekly (GPS)
CW	continuous wave
DASR	Digital Airport Surveillance Radar
db	decibel
DD	Destroyer
DDG	Guided Missile Destroyer
DEFCON	defense condition
DEG	degree
DF	direction finding
DGPS	Differential Global Positioning System

DISA	Defense Information Systems Agency
DME	distance measuring equipment
DNSO	Defense Network Systems Organization
DOT	Department of Transportation
DR	dead reckoning
drms	distance root-mean-square
DSCS	Defense Satellite Communications Systems
DSMAC	Digital Scene Matching Area Correlation
DSN	DOD voice telephone net (formerly AUTOVON)
DSRV/DSV	Deep Submergence Vehicle
DSVL	Doppler Sonar Velocity Log
EMP	electromagnetic pulse
EPLRS	enhanced version of the Position Location
ESGN	electrically suspended gyro navigation
FAA	Federal Aviation Administration
FAADS	Forward Area Air Defense System
FANS	Future Air Navigation System
FAR	Federal Aviation Regulations
FCC	Federal Communications Commission
FRP	Federal Radionavigation Plan
FY	fiscal year
GaAs	Gallium Arsenide
GANS	global access, navigation and safety
GATM	global air traffic management
GCA	ground controlled approach
GEOREF	World Geographic Reference System
GFE	government-furnished equipment
GHz	gigahertz
GI&S	geospatial information and services
GLPS	Gun-Laying Positioning System
GPS	Global Positioning System
GUV	group unique variable (GPS)
GYROS	gyroscope
HAE	host application equipment (GPS PPS User Equipment)
HF	high frequency
HR	relative height
HSL	height above mean sea level
Hz	hertz
IAF	initial approach fix
ICAO	International Civil Aviation Organization
ICNIA	Integrated Communications, Navigation, and Identification Avionics
IFCS	Improved Fire Control System
IFF	identification, friend or foe
ILS	Instrument Landing System
IMO	International Maritime Organization
IMU	inertial measuring unit
INMARSAT	International Maritime Satellite
INS	Inertial Navigation System

INTEL	intelligence
INU	inertial navigation unit
JOG	joint operations - graphic
JPALS	Joint Precision Approach and Landing System
JPATS	joint primary aircraft training system
JPO	Joint Program Office (GPS)
JROC	Joint Requirements Oversight Council
JSCP	Joint Strategic Capabilities Plan
JSMB	Joint Space Management Board
JTACMS	Joint Tactical Missile System
JTIDS	Joint Tactical Information Distribution System
kHz	kilohertz
km	kilometer
kW	kilowatt
LAAS	Local Area Augmentation System
LAT	latitude
LEP	linear error probable
LF	low frequency
LHD	amphibious assault ship
LLDR	Lightweight Laser Designator Rangefinder
LOA	Letter of Offer and Acceptance
LOC	location
LOP	line of position
LORAN	long range navigation
LORAN-C	C version of LORAN
m	meter
MAPS	Modular Azimuth Positioning System
MAPS-H	Maps With GPS
MATCALS	Marine Air Traffic Control and Landing System
MC&G	mapping, charting, and geodesy
MCS	Master Control Station (GPS)
MCW	modulated continuous wave
MED-EVAC	medical evacuation
MF	medium frequency
MHC	mine warfare ship
MHz	megahertz
Mil Std	military standard
mil	a unit of angular measurement equal to an angle having a tangent of 0.001
MLRS	multiple launch rocket system
MLS	Microwave Landing System
mm	millimeter
MMLS	Mobile Microwave Landing System
MMR	Multi-Mode Receiver
MNP	Master Navigation Plan
MNS	Mission Need Statement
MOA	memorandum of agreement
MOD	minister of defence (allied)
MRAALS	Marine Remote Area Approach and Landing System

MSC	Military Sealift Command
MTBF	mean time between failure
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIDS	navigation aids
NAVOBSY	Naval Observatory
NAVOCEANO	Naval Oceanographic Office
NCA	National Command Authorities
NDB	nondirectional beacon
NDS	Nuclear Detonation Detection System
NFAF	Naval Fleet Auxiliary Force (MSC)
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Standards and Technology
nm	nautical miles
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NOTAM	Notice to Airmen
NSA	National Security Agency
NSG	north seeking gyro
NTISSI	National Telecommunications and Information Systems Security Instruction
NUDET	nuclear detonation
ONC	operational navigation chart
OPSCAP	Operational Status Capability
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OTH	over the horizon
PADS	Position Azimuth Determining System
PALS	Precision Approach Landing System
PAR	precision approach radar
PDD	Presidential Decision Directive
PDOP	position dilution of precision
PDS	Position Determining System
PE	probable error
PHM	Guided Missile Patrol Combatant
PINS	Precise Integrated Navigation System
PISC	Phasein Steering Committee
PLGR	Precise Lightweight GPS Receiver
PLRS	Position Location Reporting System
PLSR	Precision Landing System Receiver
PMEL	precision measurement laboratory
PNT	position, navigation and time
POM	Program Objective Memorandum
Pos/Nav	positioning/navigation
PPS	Precise Positioning Service (GPS)
PRN	psuedo-random noise
PTTI	precise time and time interval
PVT	Position, Velocity and Time

R&D	research and development
RLG	ring laser gyro
rms	root-mean-square
rss	root-sum-squared
RTCA	Motto is "Requirements and Technical Concepts for Aviation"
RTCM	Radio Technical Commission Maritime
SA	selective availability (GPS)
SA/A-S	selective availability/anti-spoof
SAASM	Selective Availability/Anti-Spoof Module
SACEUR	Supreme Allied Commander, Europe
SACLANT	Supreme Allied Commander, Atlantic
SAR	search and rescue
sec	second
SEP	spherical error probable
SIAGL	survey instrument azimuth gyroscope lightweight
SIGINT	signals intelligence
sigma	standard deviation
SM	Security Module
SMC	Space and Missile Systems Center
SONAR	sound navigation ranging
SPS	Standard Positioning Service (GPS)
SRP/PDS	Stabilization Reference Package/Position Determining System
SSA	strapdown sensor assembly
SSBN	nuclear-powered fleet ballistic submarine
SSN	nuclear-powered attack submarine
SSS	satellite signal simulators (GPS)
STELLA	System to Estimate Latitude and Longitude Astronomically
TACAN	tactical air navigation
TERCOM	terrain contour matching
TERPROM	terrain profile matching
TPC/PC	tactical pilotage chart/pilotage chart
TSGCEE	Tri-Service Group on Communications and Electronic Equipment (NATO)
TSO	Technical Standard Order
UE	user equipment
UHF	ultrahigh frequency
USAF	US Air Force
USCG	US Coast Guard
USCINCSPACE	Commander in Chief, US Space Command
USCINCSTRAT	Commander in Chief, US Strategic Command
USMC	US Marine Corps
USN	US Navy
USNO	US Naval Observatory
UTC	Universal Time Coordinated
UTM	universal transverse mercator
V/STOL	Vertical/short takeoff and landing
VHF	very high frequency

VHIC	very high speed integrated circuits
VLF	very low frequency
VOR	very high frequency omnidirectional range station
VORTAC	combined VOR/TACAN Station
VTOL	vertical takeoff and landing
WAAS	Wide Area Augmentation System (GPS)
WGS 84	World Geodetic System (1984)
WGS	World Geodetic System
WWV WWVH	time station call letters
x	times
Y code	precise code (GPS)

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